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THE ROADS MUST ROLL

BY ROBERT HEINLEIN

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Contents

By Robert A. Heinlein

The higher civilization becomes, the more it is dependent on each unit—and the more it is at the mercy of a few!

"Who makes the roads roll?"

The speaker stood still on the rostrum and waited for his audience to answer him. The reply came in scattered shouts that cut through the ominous, discontented murmur of the crowd.

"We do! We do! Damn right!"

"Who does the dirty work 'down inside'—so that Joe Public can ride at his ease?"

This time it was a single roar: "We do!"

The speaker pressed his advantage, his words tumbling out in a rasping torrent. He leaned toward the crowd, his eyes picking out individuals at whom to fling

his words. "What makes business? The roads! How do they move the food they eat? The roads! How do they get to work? The roads! How do they get home to their wives? The roads!" He paused for effect, then lowered his voice. "Where would the public be if you boys didn't keep them roads rolling? Behind the eight ball, and everybody knows it. But do they appreciate it? *Pfui!* Did we ask for too much? Were our demands unreasonable? 'The right to resign whenever we want to.' Every working stiff in any other job has that. 'The same pay as the engineers.' Why not? Who are the real engineers around here? D'yuh have to be a cadet in a funny little hat before you can learn to wipe a bearing, or jack down a rotor? Who earns his keep: The gentlemen in the control offices, or the boys down inside? What else do we ask? 'The right to elect our own engineers.' Why the hell not? Who's competent to pick engineers? The technicians—or some damn dumb examining board that's never been down inside, and couldn't tell a rotor bearing from a field coil?"

He changed his pace with natural art, and lowered his voice still further. "I tell you, brother, it's time we quit fiddlin' around with petitions to the Transport Commission, and use a little direct action. Let 'em yammer about democracy; that's a lot of eyewash—we've got the power, and we're the men that count!"

A man had risen in the back of the hall while the speaker was haranguing. He spoke up as the speaker paused. "Brother chairman," he drawled, "may I stick in a couple of words?"

"You are recognized, Brother Harvey."

"What I ask is: What's all the shootin' for? We've got the highest hourly rate of pay of any mechanical guild, full insurance and retirement, and safe working conditions, barring the chance of going deaf." He pushed his antinoise helmet farther back from his ears. He was still in dungarees, apparently just up from standing watch. "Of course we have to give ninety days' notice to quit a job, but, cripes, we knew that when we signed up. The roads have got to roll—they can't stop every time some lazy punk gets tired of his billet."

"And now Soapy"—the crack of the gavel cut him short—"Pardon me, I mean *Brother* Soapy—tells us how powerful we are, and how we should go in for direct action. Rats! Sure, we could tie up the roads, and play hell with the whole community—but so could any screwball with a can of nitroglycerin, and he wouldn't have to be a technician to do it, neither.

"We aren't the only frogs in the puddle. Our jobs are important, sure, but where would we be without the farmers—or the steel workers—or a dozen other trades and professions?"

He was interrupted by a sallow little man with protruding upper teeth, who said: "Just a minute, Brother Chairman, I'd like to ask Brother Harvey a question," then turned to Harvey and inquired in a sly voice: "Are you speaking for the guild, brother—or just for yourself? Maybe you don't believe in the guild? You wouldn't by any chance be"—he stopped and slid his eyes up and down Harvey's lank frame—"a *spotter*, would you?"

Harvey looked over his questioner as if he had found something filthy in a plate of food. "Sikes," he told him, "if you weren't a runt, I'd stuff your store teeth down your throat. I helped found this guild. I was on strike in '60. Where were you in '60? With the finks?"

The chairman's gavel pounded. "There's been enough of this," he said. "Nobody that knows anything about the history of this guild doubts the loyalty of Brother Harvey. We'll continue with the regular order of business." He stopped to clear his throat. "Ordinarily, we don't open our floor to outsiders, and some of you boys have expressed a distaste for some of the engineers we work under, but there is one engineer we always like to listen to whenever he can get away from his pressing duties. I guess maybe it's because he's had dirt under his nails the same as us. Anyhow, I present at this time Mr. Shorty van Kleeck—"

A shout from the floor stopped him. "*Brother* van Kleeck!"

"O. K., Brother van Kleeck, chief deputy engineer of this roadtown."

"Thanks, Brother Chairman." The guest speaker came briskly forward, and grinned expansively at the crowd. He seemed to swell under their approval. "Thanks, brothers. I guess our chairman is right. I always feel more comfortable here in the guild hall of the Sacramento Sector—or any

guild hall for that matter—than I do in the engineers' clubhouse. Those young punk cadet engineers get in my hair. Maybe I should have gone to one of the fancy technical institutes, so I'd have the proper point of view, instead of coming up from down inside.

"Now, about those demands of yours that the Transport Commission just threw back in your face—Can I speak freely?"

"Sure you can, Shorty! You can trust us!"

"Well, of course I shouldn't say anything, but I can't help but understand how you feel. The roads are the big show these days, and you are the men who make them roll. It's the natural order of things that your opinions should be listened to, and your desires met. One would think that even politicians would be bright enough to see that. Sometimes, lying awake at night, I wonder why we technicians don't just take things over, and—"

"YOUR wife is calling, Mr. Gaines."

"Very well." He flicked off the office intercommunicator and picked up a telephone handset from his desk. "Yes, darling, I know I promised, but . . . You're perfectly right, darling, but Washington has especially requested that we show Mr. Blekinsop anything he wants to see. I didn't know he was arriving today. . . . No, I can't turn him over to a subordinate. It wouldn't be courteous. He's Minister of Transport for Australia. I told you that. . . . Yes, darling, I know that courtesy begins at home, but the roads must roll. It's my job; you knew that when you married me. And this is part of my job. . . . That's a good girl. We'll positively have breakfast together. Tell you what, order horses and a breakfast pack and we'll make it a picnic. I'll meet you in Bakersfield—usual place. . . . Good-by, darling. Kiss Junior good night for me."

He replaced the handset, whereupon the pretty but indignant features of his wife faded from the visor screen. A young woman came into his office. As she opened the door, she exposed momentarily the words painted on its outer side: "Diego-Reno Roadtown, Office of the Chief Engineer." He gave her a harassed glance.

"Oh, it's you. Don't marry an engineer, Dolores, marry an artist. They have more home life."

"Yes, Mr. Gaines. Mr. Blekinsop is here, Mr. Gaines."

"Already! I didn't expect him so soon. The Antipodes ship must have grounded early."

"Yes, Mr. Gaines."

"Dolores, don't you ever have any emotions?"

"Yes, Mr. Gaines."

"Hm-m-m, it seems incredible, but you are never mistaken. Show Mr. Blekinsop in."

"Very good, Mr. Gaines."

Larry Gaines got up to greet his visitor. Not a particularly impressive little guy, he thought, as they shook hands and exchanged formal amenities. The rolled umbrella, the bowler hat, were almost too good to be true. An Oxford accent partially masked the underlying clipped, flat, nasal twang of the native Australia.

"It's a pleasure to have you here, Mr. Blekinsop, and I hope we can make your stay enjoyable."

The little man smiled. "I'm sure it will be. This is my first visit to your wonderful country. I feel at home already. The eucalyptus trees, you know, and the brown hills—"

"But your trip is primarily business?"

"Yes, yes. My primary purpose is to study your roadcities and report to my government on the advisability of trying to adapt your startling American methods to our social problems Down Under. I thought you understood that such was the reason I was sent to you."

"Yes, I did, in a general way. I don't know just what it is that you wish to find out. I suppose that you have heard about our roadtowns, how they came about, how they operate, and so forth."

"I've read a good bit, true, but I am not a technical man, Mr. Gaines, not an engineer. My field is social and political. I want to see how this remarkable technical change has affected your people. Suppose you tell me about the roads as if I were entirely ignorant. And I will ask questions."

"That seems a practical plan. By the way, how many are there in your party?"

"Just myself. My secretary went on to Washington."

"I see." Gaines glanced at his wrist watch. "It's nearly dinner time. Suppose

we run up to the Stockton Sector for dinner. There is a good Chinese restaurant up there that I'm partial to. It will take us about an hour and you can see the ways in operation while we ride."

"Excellent."

Gaines pressed a button on his desk, and a picture formed on a large visor screen mounted on the opposite wall. It showed a strong-boned, angular young man seated at a semicircular control desk, which was backed by a complex instrument board. A cigarette was tucked in one corner of his mouth.

The young man glanced up, grinned, and waved from the screen. "Greetings and salutations, chief. "What can I do for you ?"

"Hi, Dave. You've got the evening watch, eh ? I'm running up to the Stockton Sector for dinner. Where's Van Kleeck ?"

"Gone to a meeting somewhere. He didn't say."

"Anything to report ?"

"No, sir. The roads are rolling, and all the little people are going ridey-ridey home to their dinners."

"O. K.—keep 'em rolling."

"They'll roll, chief."

Gaines snapped off the connection and turned to Blekinsop. "Van Kleeck is my chief deputy. I wish he'd spend more time on the road and less on politics. Davidson can handle things, however. Shall we go ?"

THEY GLIDED down an electric staircase, and debouched on the walkway which bordered the northbound five-mile-an-hour strip. After skirting a stairway trunk marked "Overpass to Southbound Road," they paused at the edge of the first strip. "Have you ever ridden a conveyor strip before ?" Gaines inquired. "It's quite simple. Just remember to face against the motion of the strip as you get on."

They threaded their way through homeward-bound throngs, passing from strip to strip. Down the center of the twenty-mile-an-hour strip ran a glassite partition which reached nearly to the spreading roof. The Honorable Mr. Blekinsop raised his eyebrows inquiringly as he looked at it.

"Oh, that ?" Gaines answered the unspoken question as he slid back a panel door and ushered his guest through. "That's a wind break. If we didn't have some way of separating the air currents over the strips of different speeds the wind would tear our clothes off on the hundred-mile-an-hour strip." He bent his head to Blekinsop's as he spoke, in order to cut through the rush of air against the road surfaces, the noise of the crowd, and the muted roar of the driving mechanism concealed beneath the moving strips. The combination of noises inhibited further conversation as they proceeded toward the middle of the roadway. After passing through three more wind screens located at the forty, sixty, and eighty-mile-an-hour strips respectively, they finally reached the maximum-speed strip, the hundred-mile-an-hour strip, which made the round trip, San Diego to Reno and back, in twelve hours.

Blekinsop found himself on a walkway, twenty feet wide, facing another partition. Immediately opposite him an illuminated show-window proclaimed :

JAKE'S STEAK HOUSE No. 4
The Fastest Meal on the Fastest Road!
"To dine on the fly
Makes the miles roll by!"

"Amazing !" said Mr. Blekinsop. "It would be like dining in a tram. Is this really a proper restaurant ?"

"One of the best. Not fancy, but sound."

"Oh, I say, could we—"

Gaines smiled at him. "You'd like to try it, wouldn't you, sir ?"

"I don't wish to interfere with your plans—"

"Quite all right. I'm hungry myself, and Stockton is a long hour away. Let's go in."

Gaines greeted the manageress as an old friend. "Hello, Mrs. McCoy. How are you tonight ?"

"If it isn't the chief himself ! It's a long time since we've had the pleasure of seeing your face." She led them to a booth somewhat detached from the crowd of dining commuters. "And will you and your friend be having dinner ?"

"Yes, Mrs. McCoy. Suppose you order for us—but be sure it includes one of your steaks."

"Two inches thick—from a steer that died happy." She glided away, moving her fat frame with surprising grace.

With sophisticated foreknowledge of the chief engineer's needs, Mrs. McCoy had left

a portable telephone at the table. Gaines plugged it into an accommodation jack at the side of the booth, and dialed a number. "Hello—Davidson? Dave, this is the chief. I'm in Jake's Steak House No. 4 for supper. You can reach me by calling 10-L-6-6."

He replaced the handset, and Blekinsop inquired politely: "Is it necessary for you to be available at all times?"

"Not strictly necessary," Gaines told him, "but I feel safer when I am in touch. Either Van Kleeck, or myself, should be where the senior engineer of the watch—that's Davidson this shift—can get hold of us in a pinch. If it's a real emergency, I want to be there, naturally."

"What would constitute a real emergency?"

"Two things, principally. A power failure on the rotors would bring the road to a standstill, and possibly strand millions of people a hundred miles, or more, from their homes. If it happened during a rush hour, we would have to evacuate those millions from the road—not too easy to do."

"You say millions—as many as that?"

"Yes, indeed. There are twelve million people dependent on this roadway, living and working in the buildings adjacent to it, or within five miles of each side."

THE AGE OF POWER blends into the Age of Transportation almost imperceptibly, but two events stand out as landmarks in the change: The invention of the Sun-power screen, and the opening of the first moving road. The power resources of oil and coal of the United States had—save for a few sporadic outbreaks of common sense—been shamefully wasted in their development all through the first half of the Twentieth Century. Simultaneously, the automobile, from its humble start as a one-lunged horseless carriage, grew into a steel-bodied monster of over a hundred horsepower and capable of making more than a hundred miles an hour. They boiled over the countryside, like yeast in ferment. In 1945 it was estimated that there was a motor vehicle for every two persons in the United States.

They contained the seeds of their own destruction. Seventy million steel juggernauts, operated by imperfect human beings at high speed, are more destructive than war. In the same reference year the premiums paid for compulsory liability and property damage insurance by automobile owners exceeded in amount the sum paid the same year to purchase automobiles. Safe driving campaigns were chronic phenomena, but were mere pious attempts to put Humpty-Dumpty together again. It was not physically possible to drive safely in those crowded metropolises. Pedestrians were sardonically divided into two classes, the quick and the dead.

But a pedestrian could be defined as a man who had found a place to park his car. The automobile made possible huge cities, then choked those same cities to death with their numbers. In 1900 Herbert George Wells pointed out that the saturation point in the size of a city might be mathematically predicted in terms of its transportation facilities. From a standpoint of speed alone the automobile made possible cities two hundred miles in diameter, but traffic congestion, and the inescapable, inherent danger of high-powered, individually operated vehicles canceled out the possibility.

In 1945 Federal Highway No. 66 from Los Angeles to Chicago, "The Main Street of America," was transformed into a superhighway for motor vehicles, with an underspeed limit of sixty miles per hour. It was planned as a public works project to stimulate heavy industry; it had an unexpected by-product. The great cities of Chicago and St. Louis stretched out urban pseudopods toward each other, until they met near Bloomington, Illinois. The two parent cities actually shrunk in population.

The same year the city of San Francisco replaced its antiquated cable cars with moving stairways, powered with the Douglas-Martin Solar Reception Screens. The largest number of automobile licenses in history had been issued that calendar year, but the end of the automobile was in sight. The National Defense Act of 1947 closed its era.

This act, one of the most bitterly debated ever to be brought out of committee, declared petroleum to be an essential and limited material of war. The army and navy had first call on all oil, above or below the ground, and seventy million civilian vehicles faced short and expensive rations.

Take the superhighways of the period, urban throughout their length. Add the mechanized streets of San Francisco's hills. Heat to boiling point with an imminent shortage of gasoline. Flavour with Yankee

ingenuity. The first mechanized road was opened, in 1950, between Cincinnati and Cleveland.

It was, as one would expect, comparatively primitive in design. The fastest strip moved only thirty miles per hour, and was quite narrow, for no one had thought of the possibility of locating retail trade on the strips themselves. Nevertheless, it was a prototype of the social pattern which was to dominate the American scene within the next two decades—neither rural nor urban, but partaking equally of both, and based on rapid, safe, cheap, convenient transportation.

Factories—wide, low buildings whose roofs were covered with solar power screens of the same type that drove the road—lined the roadway on each side. Back of them and interspersed among them were commercial hotels, retail stores, theaters, apartment houses. Beyond this long, thin, narrow strip was the open countryside, where much of the population lived. Their homes dotted the hills, hung on the banks of creeks, and nestled between the farms. They worked in the "city," but lived in the "country"—and the two were not ten minutes apart.

MRS. MCCOY served the chief and his guest in person. They checked their conversation at the sight of the magnificent steaks.

Up and down the six-hundred-mile line, sector engineers of the watch were getting in their hourly reports from their subsector technicians. "Subsector One — check!" "Subsector Two—check!" Tensiometer readings, voltage, load, bearing temperatures synchrotachometer readings — "Subsector Seven—check!" Hard-bitten, able men in in dungarees, who lived much of their lives down inside amidst the unmuted roar of the hundred-mile strip, the shrill whine of driving rotors, and the complaint of the relay rollers.

Davidson studied the moving model of the road, spread out before him in the main control room at Fresno Sector. He watched the barely perceptible crawl of the miniature hundred-mile strip and subconsciously noted the reference number on it which located Jake's Steak House No. 4. The chief would be getting into Stockton soon; he'd give him a ring after the hourly reports were in. Everything was quiet; traffic tonnage normal for rush hour; he would be sleepy before this watch was over. He turned to his cadet engineer of the watch. "Mr. Barnes."

"Yes, sir."

"I think we could use some coffee."

"Good idea, sir. I'll order some as soon as the hourlies are in."

The minute hand of the control board chronometer reached twelve. The cadet watch officer threw a switch. "All sectors, report!" he said, in crisp, self-conscious tones.

The faces of two men flicked into view on the visor screen. The younger answered him with the same air of acting under supervision. "Diego Circle—rolling!"

They were at once replaced by two more. "Angeles Sector—rolling!"

Then: "Bakerfield Sector—rolling!"

And: "Stockton Sector—rolling!"

Finally, when Reno Circle had reported, the cadet turned to Davidson and reported: "Rolling, sir."

"Very well—keep them rolling!"

The visor screen flashed on once more. "Sacramento Sector — supplementary report."

"Proceed."

"Cadet Engineer Guenther, while on visual inspection as cadet sector engineer of the watch, found Cadet Engineer Alec Jeans, on watch as cadet subsector technician, and R. J. Ross, technician second class, on watch as technician for the same subsector, engaged in playing cards. It was not possible to tell with any accuracy how long they had neglected to patrol their subsector."

"Any damage?"

"One rotor running hot, but still synchronized. It was jacked down, and replaced."

"Very well. Have the paymaster give Ross his time, and turn him over to the civil authorities. Place Cadet Jeans under arrest and order him to report to me."

"Very well, sir."

"Keep them rolling!"

Davidson turned back to the control desk and dialed Chief Engineer Gaines' temporary number.

"YOU MENTIONED that there were two things that could cause major trouble on

the road Mr. Gaines, but you spoke only of power failure to the rotors."

Gaines pursued an elusive bit of salad before answering. "There really isn't a second major trouble—it won't happen. However—we are traveling along here at one hundred miles per hour. Can you visualize what would happen if this strip under us should break?"

Mr. Blekinsop shifted nervously in his chair. "Hm-m-m! Rather a disconcerting idea, don't you think? I mean to say, one is hardly aware that one is traveling at high speed, here in this snug room. What *would* the result be?"

"Don't let it worry you; the strip can't part. It is built up of overlapping sections in such a fashion that it has a safety factor of better than twelve to one. Several miles of rotors would have to shut down all at once, and the circuit breakers for the rest of the line fail to trip out before there could possibly be sufficient tension on the strip to cause it to part.

"But it happened once, on the Philadelphia-Jersey City road, and we aren't likely to forget it. It was one of the earliest high-speed roads, carrying a tremendous passenger traffic, as well as heavy freight, since it serviced a heavily industrialized area. The strip was hardly more than a conveyor belt, and no one had foreseen the weight it would carry. It happened under maximum load, naturally, when the high-speed way was crowded. The part of the strip behind the break buckled for miles, crushing passengers against the roof at eighty miles per hour. The section forward of the break cracked like a whip, spilling passengers onto the slower ways, dropping them on the exposed rollers and rotors down inside, and snapping them up against the roof.

"Over three thousand people were killed in that one accident, and there was much agitation to abolish the roads. They were even shut down for a week by presidential order, but he was forced to reopen them again. There was no alternative."

"Really? Why not?"

"The country had become economically dependent on the roads. They were the principal means of transportation in the industrial areas—the only means of economic importance. Factories were shut down; food didn't move; people got hungry—and the president was forced to let them roll again. It was the only thing that could be done; the social pattern had crystallized in one form, and it couldn't be changed overnight. A large, industrialized population must have large-scale transportation, not only for people, but for trade."

Mr. Blekinsop fussed with his napkin, and rather diffidently suggested: "Mr. Gaines, I do not intend to disparage the ingenious accomplishments of your great people, but isn't it possible that you may have put too many eggs in one basket in allowing your whole economy to become dependent on the functioning of one type of machinery?"

Gaines considered this soberly. "I see your point. Yes—and no. Every civilization above the peasant-and-village type is dependent on some key type of machinery. The old South was based on the cotton gin. Imperial England was made possible by the steam engine. Large populations have to have machines for power, for transportation, and for manufacturing in order to live. Had it not been for machinery the large populations could never have grown up. That's not a fault of the machine; that's its virtue.

"But it is true that whenever we develop machinery to the point where it will support large populations at a high standard of living we are then bound to keep that machinery running, or suffer the consequences. But the real hazard in that is not the machinery, but the men who run the machinery. These roads, as machines, are all right. They are strong and safe and will do everything they were designed to do. No, it's not the machines, it's the men.

"When a population is dependent on a machine, they are hostages of the men who tend the machines. If their morale is high, their sense of duty strong—"

Someone up near the front of the restaurant had turned up the volume control of the radio, letting out a blast of music that drowned out Gaines' words. When the sound had been tapered down to a more nearly bearable volume, he was saying:

"Listen to that. It illustrates my point."

BLEKINSOP turned an ear to the music. It was a swinging march of compelling rhythm, with a modern interpretive arrangement. One could hear the roar of machinery, the repetitive clatter of mechanisms. A

pleased smile of recognition spread over the Australian's face. "It's your field artillery song, 'The Roll of the Caissons,' isn't it? But I don't see the connection."

"You're right; it *was* 'The Roll of the Caissons,' but we adapted it to our own purposes. It's 'The Road Song of the Transport Cadets,' too. Wait!"

The persistent throb of the march continued, and seemed to blend with the vibration of the roadway underneath into a single timpano. Then a male chorus took up the verse:

"Hear them hum!
Watch them run!
Oh, our job is never done,
For our roadways go rolling along!
While you ride;
While you glide;
We are watching down inside,
So your roadways keep rolling along!

"Oh, it's Hie! Hie! Hee!
The rotor men are we—
Check off the sectors loud and strong!
ONE! TWO! THREE!
Anywhere you go
You are bound to know
That your roadways are rolling along!
KEEP THEM ROLLING!
That your roadways are rolling along!"

"See?" said Gaines, with more animation in his voice. "See? That is the real purpose of the United States Academy of Transport. That is the reason why the transport engineers are a semimilitary profession, with strict discipline. We are the bottle neck, the *sine qua non*, of all industry, all economic life. Other industries can go on strike, and only create temporary and partial dislocations. Crops can fail here and there, and the country takes up the slack. But if the roads stop rolling, everything else must stop; the effect would be the same as a general strike—with this important difference: It takes a majority of the population, fired by a real feeling of grievance, to create a general strike; but the men that run the roads, few as they are, can create the same complete paralysis.

"We had just one strike on the roads, back in '60. It was justified, I think, and it corrected a lot of real abuses—but it mustn't happen again."

"But what is to prevent it happening again, Mr. Gaines?"

"Morale—ésprit de corps. The technicians in the road service are indoctrinated constantly with the idea that their job is a sacred trust. Besides, we do everything we can to build up their social position. But even more important is the academy. We try to turn out graduate engineers imbued with the same loyalty, the same iron self-discipline and determination to perform their duty to the community at any cost, that Annapolis and West Point and Goddard are so successful in inculcating in their graduates."

"Goddard? Oh, yes, the rocket field. And have you been successful, do you think?"

"Not entirely, perhaps, but we will be. It takes time to build up a tradition. When the oldest engineer is a man who entered the academy in his teens, we can afford to relax a little and treat it as a solved problem."

"I suppose you are a graduate?"

Gaines grinned. "You flatter me—I must look younger than I am. No, I'm a carry-over from the army. You see, the war department operated the roads for some three months during reorganization after the strike in '60. I served on the conciliation board that awarded pay increases and adjusted working conditions, then I was assigned—"

The signal light of the portable telephone glowed red. Gaines said, "Excuse me," and picked up the handset. "Yes?"

Blekinsop could overhear the voice at the other end. "This is Davidson, chief. The roads are rolling."

"Very well. Keep them rolling!"

"Had another trouble report from the Sacramento Sector."

"Again? What this time?"

Before Davidson could reply he was cut off. As Gaines reached out to dial him back, his coffee cup, half full, landed in his lap. Blekinsop was aware, even as he was lurched against the edge of the table, of a disquieting change in the hum of the roadway.

"What has happened, Mr. Gaines?"

"Don't know. Emergency stop—God knows why." He was dialing furiously. Shortly he flung the phone down, without bothering to return the handset to its cradle. "Phones are out. Come on! No! You'll be safe here. Wait."

"Must I?"

"Well, come along then, and stick close to me." He turned away, having dis-

missed the Australian cabinet minister from his mind. The strip ground slowly to a rest, the giant rotors and myriad rollers acting as flywheels in preventing a disastrous sudden stop. Already a little knot of commuters, disturbed at their evening meal, were attempting to crowd out the door of the restaurant.

"Halt!"

There is something about a command issued by one used to being obeyed which enforces compliance. It may be intonation, or possibly a more esoteric power, such as animal tamers are reputed to be able to exercise in controlling ferocious beasts. But it does exist, and can be used to compel even those not habituated to obedience.

The commuters stopped in their tracks.

Gaines continued: "Remains in the restaurant until we are ready to evacuate you. I am the chief engineer. You will be in no danger here. You!" He pointed to a big fellow near the door. "You're deputized. Don't let anyone leave without proper authority. Mrs. McCoy, resume serving dinner."

GAINES strode out the door, Blekinsop tagging along. The situation outside permitted no such simple measures. The hundred-mile strip alone had stopped; twenty feet away the next strip flew by at an unchecked ninety-five miles an hour. The passengers on it flickered past, unreal cardboard figures.

The twenty-foot walkway of the maximum speed strip had been crowded when the breakdown occurred. Now the customers of shops, of lunch stands, and of other places of business, the occupants of lounges, of television theatres—all came crowding out onto the walkway to see what had happened. The first disaster struck almost immediately.

The crowd surged, and pushed against a middle-aged woman on its outer edge. In attempting to recover her balance she put one foot over the edge of the flashing ninety-five-mile strip. She realized her gruesome error, for she screamed before her foot touched the ribbon.

She spun around and landed heavily on the moving strip, and was rolled by it, as the strip attempted to impart to her mass, at one blow, a velocity of ninety-five miles per hour—one hundred and thirty-nine feet per second. As she rolled she mowed down some of the cardboard figures as a sickle strikes a stand of grass. Quickly, she was out of sight, her identity, her injuries, and her fate undetermined, and already remote.

But the consequences of her mishap were not done with. One of the flickering cardboard figures bowled over by her relative moment fell toward the hundred-mile strip, slammed into the shockbound crowd, and suddenly appeared as a live man—but broken and bleeding—amidst the luckless, fallen victims whose bodies had checked his wild flight.

Even there it did not end. The disaster spread from its source, each hapless human ninepin more likely than not to knock down others so that they fell over the danger-laden boundary, and in turn ricocheted to a dearly-bought equilibrium.

But the focus of calamity sped out of sight, and Blekinsop could see no more. His active mind, accustomed to dealing with large numbers of individual human beings, multiplied the tragic sequence he had witnessed by twelve hundred miles of thronged conveyor strip, and his stomach chilled.

To Blekinsop's surprise, Gaines made no effort to succor the fallen, nor to quell the fear-infected mob, but turned an expressionless face back to the restaurant. When Blekinsop saw that he was actually reentering the restaurant, he plucked at Gaines' sleeve. "Aren't we going to help those poor people?"

The cold planes of the face of the man who answered him bore no resemblance to his genial, rather boyish host of a few minutes before. "No. Bystanders can help them—I've got the whole road to think of. Don't bother me."

Crushed, and somewhat indignant, the politician did as he was ordered. Rationally, he knew that the chief engineer was right—a man responsible for the safety of millions cannot turn aside from his duty to render personal service to one—but the cold detachment of such viewpoint was repugnant to him.

Gaines was back in the restaurant. "Mrs. McCoy, where is your getaway?"

"In the pantry, sir."

Gaines hurried there, Blekinsop at his heels. A nervous Filipino salad boy shrank out of Gaines' way as he casually swept a supply of prepared green stuffs onto the

floor, and stepped up on the counter where they had rested. Directly above his head and within reach was a circular manhole, counterweighted and operated by a hand-wheel set in its center. A short steel ladder, hinged to the edge of the opening, was swung up flat to the ceiling and secured by a hook.

Blekinsop lost his hat in his endeavor to clamber quickly enough up the ladder after Gaines. When he emerged on the roof of the building, Gaines was searching the ceiling of the roadway with a pocket flash-light. He was shuffling along, stooped double in the awkward four feet of space between the roof underfoot and ceiling.

He found what he sought, some fifty feet away—another manhole similar to the one they had used to escape from below. He spun the wheel of the lock, and stood up in the space, then rested his hands on the sides of the opening, and with a single lithe movement vaulted to the roof of the roadways. His companion followed him with more difficulty.

They stood in darkness, a fine, cold rain feeling at their faces. But underfoot, and stretching beyond sight on each hand, the Sun-power screens glowed with a faint opalescent radiance, their slight percentage of inefficiency as transformers of radiant Sun power to available electrical power being evidenced as a mild induced radioactivity. The effect was not illumination, but rather like the ghostly sheen of a snow-covered plain seen by starlight.

THE GLOW picked out the path they must follow to reach the rain-obscured wall of buildings bordering the ways. The path was a narrow black stripe which arched away into the darkness over the low curve of the roof. They started away on this path at a dogtrot, making as much speed as the slippery footing and the dark permitted, while Blekinsop's mind still fretted at the problem of Gaines' apparently callous detachment. Although possessed of a keen intelligence, his nature was dominated by a warm, human sympathy, without which no politician, irrespective of other virtues or shortcomings, is long successful.

Because of this trait he distrusted instinctively any mind which was guided by logic alone. He was aware that, from a standpoint of strict logic, no reasonable case could be made out for the continued existence of the human race, still less for the human values he served.

Had he been able to pierce the preoccupation of his companion, he would have been reassured. On the surface, Gaines' exceptionally intelligent mind was clicking along with the facile ease of an electro-mechanical integrator—arranging data at hand, making tentative decisions, postponing judgments without prejudice until necessary data were available, exploring alternatives. Underneath, in a compartment insulated by stern self-discipline from the acting theater of his mind, his emotions were a torturing storm of self reproach. He was heartsick at the suffering he had seen, and which he knew too well was duplicated up and down the line. Although he was not aware of any personal omission, nevertheless the fault was somehow his, for authority creates responsibility.

He had carried too long the superhuman burden of kingship—which no sane mind can carry light-heartedly—and was at this moment perilously close to the frame of mind which sends captains down with their ships. But the need for immediate, constructive action sustained him.

But no trace of this conflict reached his features.

At the wall of buildings glowed a green line of arrows, pointing to the left. Over them, at the terminus of the narrow path, shone a sign: "Access down." They pursued this, Blekinsop puffing in Gaines' wake, to a door let in the wall, which gave into a narrow stairway lighted by a single glow tube. Gaines plunged down this, still followed, and they emerged on the crowded, noisy, stationary walkway adjoining the northbound road.

Immediately adjacent to the stairway, on the right, was a public telebooth. Through the glassite door they could see a portly, well-dressed man speaking earnestly to his female equivalent, mirrored in the visor screen. Three other citizens were waiting outside the booth.

GAINES pushed past them, flung open the door, grasped the bewildered and indignant man by the shoulders and hustled him outside, kicking the door closed after him. He cleared the visor screen with one sweep of his hand, before the matron

pictured therein could protest, and pressed the emergency-priority button.

He dialed his private code number, and was shortly looking into the troubled face of his engineer of the watch, Davidson.

"Report!"

"It's you, chief! Thank God! Where are you?" Davidson's relief was pathetic.

"Report!"

The senior watch officer repressed his emotion, and complied in direct, clipped phrases: "At 7.09 p.m. the consolidated tension reading, Strip 20, Sacramento Sector, climbed suddenly. Before action could be taken, tension on Strip 20 passed emergency level; the interlocks acted, and power to subject strip cut out. Cause of failure unknown. Direct communication to Sacramento control office has failed. They do not answer the auxiliary, nor commercial. Effort to re-establish communication continues. Messenger dispatched from Stockton Subsector 10.

"No casualties reported. Warning broadcast by public announcement circuit to keep clear of Strip 19. Evacuation has commenced."

"There are casualties," Gaines cut in. "Police and hospital emergency routine. Move!"

"Yes, sir!" Davidson snapped back, and hooked a thumb over his shoulder—but his cadet officer of the watch had already jumped to comply. "Shall I cut out the rest of the road, chief?"

"No. No more casualties are likely after the first disorder. Keep up the broadcast warnings. Keep those other strips rolling, or we will have a traffic jam the devil himself couldn't untangle."

Gaines had in mind the impossibility of bringing the strips up to speed under load. The rotors were not powerful enough to do this. If the entire road was stopped, he would have to evacuate every strip, correct the trouble on Strip 20, bring all strips up to speed, and then move the accumulated peak-load traffic. In the meantime, over five million stranded passengers would constitute a tremendous police problem. It was simpler to evacuate passengers on Strip 20 over the roof, and allow them to return home, via the remaining strips.

"Notify the mayor and the governor that I have assumed emergency authority. Same to the chief of police and place him under your orders. Tell the commandant to arm all cadets available and await orders. Move!"

"Yes, sir. Shall I recall technicians off watch?"

"No. This isn't an engineering failure. Take a look at your readings; that entire sector went out simultaneously. Somebody cut out those rotors by hand. Place off-watch technicians on standby status—but don't arm them, and don't send them down inside. Tell the commandant to rush all available senior-class cadets to Stockton Subsector Office No. 10 to report to me. I want them equipped with tumble-bugs, pistols, and sleep-gas bombs."

"Yes, sir." A clerk leaned over Davidson's shoulder and said something in his ear. "The governor wants to talk to you, chief."

"Can't do it—nor can you. Who's your relief? Have you sent for him?"

"Hubbard—he's just come in."

"Have him talk to the governor, the mayor, the press—anybody that calls—even the White House. You stick to your watch. I'm cutting off. I'll be back in communication as quickly as I can locate a reconnaissance car." He was out of the booth almost before the screen cleared.

BLEKINSOP did not venture to speak, but followed him out to the northbound twenty-mile strip. There Gaines stopped, short of the windbreak, turned, and kept his eyes on the wall beyond the stationary walkway. He picked out some landmark or sign—not apparent to his companion—and did an Eliza crossing the ice back to the walkway, so rapidly that Blekinsop was carried some hundred feet beyond him, and almost failed to follow when Gaines ducked into a doorway, and ran down a flight of stairs.

They came out on a narrow lower walkway, down inside. The pervading din claimed them, beat upon their bodies as well as their ears. Dimly, Blekinsop perceived their surroundings as he struggled to face that wall of sound. Facing him, illuminated by the red monochrome of a neon arc, was one of the rotors that drove the five-mile strip, its great, drum-shaped armature revolving slowly around the stationary field coils in its core. The upper surface of the drum pressed against the

under side of the moving way and imparted to it its stately progress.

To the left and right, a hundred yards each way, and beyond at similar intervals, farther than he could see, were other rotors. Bridging the gaps between the rotors were the slender rollers, crowded together like cigars in a box, in order that the strip might have a continuous rolling support. The rollers were supported by steel-girder arches through the gaps of which he saw row after row of rotors in staggered succession, the rotors in each succeeding row turning over more rapidly than the last.

Separated from the narrow walkway by a line of supporting steel pillars, and lying parallel to it on the side away from the rotors, ran a shallow paved causeway, joined to the walk at this point by a ramp. Gaines peered up and down this tunnel in evident annoyance. Blekinsop started to ask him what troubled him, but found his voice snuffed out by the sound. He could not cut through the roar of thousands of rotors and the whine of hundreds of thousands of rollers.

Gaines saw his lips move, and guessed at the question. He cupped his hands around Blekinsop's right ear, and shouted: "No car—I expected to find a car here."

The Australian, wishing to be helpful, grasped Gaines' arm and pointed back into the jungle of machinery. Gaines' eye followed the direction indicated and picked out something that he had missed in his preoccupation—a half dozen men working around a rotor several strips away. They had jacked down a rotor until it was no longer in contact with the road surface, and were preparing to replace it *in toto*. The replacement rotor was standing by on a low, heavy truck.

The chief engineer gave a quick smile of acknowledgment and thanks, and aimed his flashlight at the group, the beam focused down to a slender, intense needle of light. One of the technicians looked up, and Gaines snapped the light on and off in a repeated, irregular pattern. A figure detached itself from the group and ran toward them.

It was a slender young man, dressed in dungarees, and topped off with ear pads and an incongruous, pillbox cap, bright with gold braid and insignia. He recognized the chief engineer and saluted, his face falling into humorless, boyish intentness.

Gaines stuffed his torch into a pocket and commenced to gesticulate rapidly with both hands—clear, clean gestures, as involved and as meaningful as deaf-mute language. Blekinsop dug into his own dilettante knowledge of anthropology and decided that it was most like an American Indian sign language, with some of the finger movements of hula. But it was necessarily almost entirely strange, being adapted for a particular terminology.

The cadet answered him in kind, stepped to the edge of the causeway, and flashed his torch to the south. He picked out a car, still some distance away, but approaching at headlong speed. It braked, and came to a stop alongside them.

It was a small affair, ovoid in shape, and poised on two centerline wheels. The forward, upper surface swung up and disclosed the driver, another cadet. Gaines addressed him briefly in sign language, then hustled Blekinsop ahead of him into the cramped passenger compartment.

As the glassite hood was being swung back into place, a blast of wind smote them, and the Australian looked up in time to glimpse the last of three much larger vehicles hurtle past them. They were headed north, at a speed of not less than two hundred miles per hour. Blekinsop thought that he had made out the little hats of cadets through the windows of the last of the three, but he could not be sure.

He had no time to wonder, so violent was the driver's getaway. Gaines ignored the accelerating surge—he was already calling Davidson on the built-in communicator. Comparative silence had settled down once the car was closed. The face of a female operator at the relay station showed on the screen.

"Get me Davidson—senior watch office!"

"Oh! It's Mr. Gaines! The mayor wants to talk to you, Mr. Gaines."

"Refer him—and get me Davidson. Move!"

"Yes, sir."

"And see here—leave this circuit hooked in to Davidson's board until I tell you personally to cut it."

"Right." Her face gave way to the watch officer's.

"That you, chief? We're moving—progress O. K.—no change."

"Very well. You'll be able to raise me

on this circuit, or at Subsector 10 office. Clearing now." Davidson's face gave way to the relay operator.

"Your wife is calling, Mr. Gaines. Will you take it?"

Gaines muttered something not quite gallant, and answered: "Yes."

Mrs. Gaines flashed into facsimile. He burst into speech before she could open her mouth. "Darling I'm all right don't worry I'll be home when I get there I've got to go now." It was all out in one breath, and he slapped the control that cleared the screen.

They slammed to a breath-taking stop alongside the stair leading to the watch office of Subsector 10, and piled out. Three big lorries were drawn up on the ramp, and three platoons of cadets were ranged in restless ranks alongside them. Tumble-bugs —small, open monocycles, used to patrol down inside—were ready nearby.

A cadet trotted up to Gaines and saluted. "Lindsay, sir—cadet engineer of the watch. The engineer of the watch requests that you come at once to the control room."

The engineer of the watch looked up as they came in. "Chief—Van Kleeck is calling you."

"Put him on."

When Van Kleeck appeared in the big visor, Gaines greeted him with: "Hello, Van. Where are you?"

"Sacramento office. Now listen—"

"Sacramento? That's good! Report."

Van Kleeck looked disgruntled. "Report, hell! I'm not your deputy any more, Gaines. Now, you—"

"What the hell are you talking about?"

"Listen, and don't interrupt me, and you'll find out. You're through, Gaines. I've been picked as Director of the Provisional Control Committee for the New Order."

"Van, have you gone off your rocker? What do you mean—the 'New Order'?"

"You'll find out. This is it—the Functionalist revolution. We're in; you're out. We stopped Strip 20 just to give you a little taste of what we can do."

CONCERNING FUNCTION: *A Treatise on the Natural Order in Society*, the Bible of the Functionalist movement, was first published in 1930. It claimed to be a scientifically accurate theory of social relations. The author, Paul Decker, disclaimed the "outworn and futile" ideas of democracy and human equality, and substituted a system in which human beings were evaluated "functionally"—that is to say, by the role each filled in the economic sequence. The underlying thesis was that it was right and proper for a man to exercise over his fellows whatever power was inherent in his function, and that any other form of social organization was silly, visionary, and contrary to the "natural order."

The complete interdependence of modern economic life seems to have escaped him entirely.

His ideas were dressed up with a glib mechanistic pseudopsychology based on the observed orders of precedence among barnyard fowls, and on the famous Pavlov conditioned reflex experiments on dogs. He failed to note that human beings are neither dogs nor chickens. Old Dr. Pavlov ignored him entirely, as he had ignored so many others who had blindly and unscientifically dogmatized about the meaning of his important, but strictly limited, experiments.

Functionalism did not take hold at once—during the '30s almost everyone, from truck driver to hat-check girl, had a scheme for setting the world right in six easy lessons; and a surprising percentage managed to get their schemes published. But it gradually spread. Functionalism was particularly popular among little people everywhere who could persuade themselves that their particular jobs were the indispensable ones, and that therefore, under the "natural order," they would be top dogs. With so many different functions actually indispensable such self-persuasion was easy.

GAINES STARED at Van Kleeck for a moment before replying. "Van," he said slowly, "you don't really think you can get away with this, do you?"

The little man puffed out his chest. "Why not? We *have* gotten away with it. You can't start Strip 20 until I am ready to let you, and I can stop the whole road, if necessary."

Gaines was becoming uncomfortably aware that he was dealing with unreasonable conceit, and held himself patiently in check. "Sure you can, Van—but how about the rest of the country? Do you think the United States army will sit

quietly by and let you run California as your private kingdom?"

Van Kleeck looked sly. "I've planned for that. I've just finished broadcasting a manifesto to all the road technicians in the country, telling them what we have done, and telling them to arise, and claim their rights. With every road in the country stopped, and people getting hungry, I reckon the president will think twice before sending the army to tangle with us. Oh, he could send a force to capture, or kill, me—I'm not afraid to die!—but he doesn't dare start shooting down road technicians as a class, because the country can't get along without us—consequently, he'll have to get along with us—on our terms!"

There was much bitter truth in what he said. If an uprising of the road technicians became general, the government could no more attempt to settle it by force than a man could afford to cure a headache by blowing out his brains. But was the uprising general?

"Why do you think that the technicians in the rest of the country will follow your lead?"

"Why not? It's the natural order of things. This is an age of machinery; the real power everywhere is in the technicians, but they have been kidded into not using their power with a lot of obsolete catch phrases. And of all the classes of technicians, the most important, the absolutely essential, are the road technicians. From now on they run the show—it's the natural order of things!" He turned away for a moment and fussed with some papers on the desk before him; then he added: "That's all for now, Gaines—I've got to call the White House, and let the President know how things stand. You carry on, and behave yourself, and you won't get hurt."

Gaines sat quite still for some minutes after the screen cleared. So that's how it was. He wondered what effect, if any, Van Kleeck's invitation to strike had had on road technicians elsewhere. None, he thought—but then he had not dreamed that it could happen among his own technicians. Perhaps he had made a mistake in refusing to take time to talk to anyone outside the road. No—if he had stopped to talk to the governor, or the newspapermen, he would still be talking. Still—

He dialed Davidson.

"Any trouble in any other sectors, Dave?"

"No, chief."

"Or on any other road?"

"None reported."

"Did you hear my talk with Van Kleeck?"

"I was cut in—yes."

"Good. Have Hubbard call the President and the governor, and tell them that I am strongly opposed to the use of military force as long as the outbreak is limited to this one road. Tell them that I will not be responsible if they move in before I ask for help."

Davidson looked dubious. "Do you think that is wise, chief?"

"I do! If we try to blast Van and his red-hots out of their position, we may set off a real, countrywide uprising. Furthermore, he could wreck the road so that God Himself couldn't put it back together. What's your rolling tonnage now?"

"Fifty-three percent under evening peak."

"How about Strip 20?"

"Almost evacuated."

"Good. Get the road clear of all traffic as fast as possible. Better have the chief of police place a guard on all entrances to the road to keep out new traffic. Van may stop all the strips any time—or I may need to myself. Here is my plan: I'm going down inside with these armed cadets. We will work north, overcoming any resistance we meet. You arrange for watch technicians and maintenance crews to follow immediately behind us. Each rotor, as they come to it, is to be cut out, then hooked into the Stockton control board. It will be a haywire rig, with no safety interlocks, so use enough watch technicians to be able to catch trouble before it happens.

"If this scheme works, we can move control of the Sacramento Sector right out from under Van's feet, and he can stay in his Sacramento control office until he gets hungry enough to be reasonable."

He cut off and turned to the subsector engineer of the watch. "Edmunds, give me a helmet—and a pistol."

"Yes, sir." He opened a drawer, and handed his chief a slender, deadly-looking weapon. Gaines belted it on, and accepted a helmet, into which he crammed his head, leaving the antinoise ear flaps up. Blekinsop cleared his throat.

"May . . . uh . . . may I have one of those helmets?" he inquired.

"What?" Gaines focused his attention. "Oh— You won't need one, Mr. Blekinsop. I want you to remain right here until you hear from me."

"But—" The Australian statesman started to speak, thought better of it, and subsided.

FROM the doorway the cadet engineer of the watch demanded the chief engineer's attention. "Mr. Gaines, there is a technician out here who insists on seeing you —a man named Harvey."

"Can't do it."

"He's from the Sacramento Sector, sir."

"Oh! Send him in."

Harvey quickly advised Gaines of what he had seen and heard at the guild meeting that afternoon. "I got disgusted and left while they were still jawin', chief. I didn't think any more about it until Strip 20 stopped rolling. Then I heard that the trouble was in Sacramento Sector, and decided to look you up."

"How long has this been building up?"

"Quite some time, I guess. You know how it is. There are a few soreheads everywhere, and a lot of them are Functionalists. But you can't refuse to work with a man just because he holds different political views. It's a free country."

"You should have come to me before, Harvey." Harvey looked stubborn. Gaines studied his face. "No, I guess you are right. It's my business to keep tabs on your mates, not yours. As you say, it's a free country. Anything else?"

"Well—now that it has come to this, I thought maybe I could help you pick out the ringleaders."

"Thanks. You stick with me. We are going down inside and try to clear up this mess."

The office door opened suddenly, and a technician and a cadet appeared, lugging a burden between them. They deposited it on the floor, and waited.

It was a young man, quite evidently dead. The front of his dungaree jacket was soggy with blood. Gaines looked at the watch officer. "Who is he?"

Edmunds broke his stare and answered: "Cadet Hughes. He's the messenger I sent to Sacramento when communication failed. When he didn't report, I sent Marston and Cadet Jenkins after him."

Gaines muttered something to himself, and turned away. "Come along, Harvey."

The cadets waiting below had changed in mood. Gaines noted that the boyish intentness for excitement had been replaced by something uglier. There was much exchange of hand signals and several appeared to be checking the loading of their pistols.

He sized them up, then signaled to the cadet leader. There was a short interchange of signals. The cadet saluted, turned to his men, gesticulated briefly, and brought his arm down smartly. They filed upstairs, and into an empty standby room, Gaines following.

Once inside, and the noise shut out, he addressed them: "You saw Hughes brought in. How many of you want a chance to kill the louse that did it?"

Three of the cadets reacted almost at once, breaking ranks and striding forward. Gaines looked at them coldly. "Very well. You three turn in your weapons, and return to your quarters. Any of the rest of you that think this is a matter of private revenge, or a hunting party, may join them." He permitted a short silence to endure before continuing. "Sacramento Sector has been seized by unauthorized persons. We are going to retake it—if possible, without loss of life on either side, and, if possible, without stopping the roads. The plan is to take over down inside, rotor by rotor, and cross-connect through Stockton. The task assignment of this group is to proceed north down inside, locating and overpowering all persons in your path. You will bear in mind the probability that most of the persons you will arrest are completely innocent. Consequently, you will favor the use of sleep-gas bombs, and will shoot to kill only as a last resort.

"Cadet captain, assign your men in squads of ten each, with squad leader. Each squad is to form a skirmish line across down inside, mounted on tumblebugs, and will proceed north at fifteen miles per hour. Leave an interval of one hundred yards between successive waves of skirmishers. Whenever a man is sighted, the entire leading wave will converge on him, arrest him, and deliver him to a transport car, then reform in the rear of the last wave. You will assign the transports that delivered

you here to hold prisoners. Instruct the drivers to keep abreast of the second wave.

"You will assign an attack group to recapture subsector control offices, but no office is to be attacked until its subsector has been cross-connected with Stockton. Arrange liaison accordingly.

"Any questions?" He let his eyes run over the faces of the young men. When no one spoke up, he turned back to the cadet in charge. "Very well, sir. Carry out your orders!"

BY THE TIME the dispositions had been completed, the follow-up crew of technicians had arrived, and Gaines had given the engineer in charge his instructions. The cadets "stood to horse" alongside their poised tumblebugs. The cadet captain looked expectantly at Gaines. He nodded, the cadet brought his arm down smartly, and the first wave mounted and moved off.

Gaines and Harvey mounted tumblebugs, and kept abreast of the cadet captain, some twenty-five yards behind the leading wave. It had been a long time since the chief engineer had ridden one of these silly-looking little vehicles, and he felt awkward. A tumblebug does not give a man dignity, since it is about the size and shape of a kitchen stool, gyro-stabilized on a single wheel. But it is perfectly adapted to patrolling the maze of machinery down inside, since it can go through an opening the width of a man's shoulders, is easily controlled, and will stand patiently upright, waiting, should its rider dismount.

The little reconnaissance car followed Gaines at a short interval, weaving in and out among the rotors, while the television and audio communicator inside continued as Gaines' link to his other manifold responsibilities.

The first two hundred yards of Sacramento Sector passed without incident, then one of the skirmishers sighted a tumblebug parked by a rotor. The technician it served was checking the gauges at the rotor's base, and did not see them approach. He was unarmed and made no resistance, but seemed surprised and indignant, as well as very bewildered.

The little command group dropped back and permitted the new leading wave to overtake them.

Three miles farther along the score stood thirty-seven men arrested, none killed. Two of the cadets had received minor wounds, and had been directed to retire. Only four of the prisoners had been armed; one of these Harvey had been able to identify definitely as a ringleader. Harvey expressed a desire to attempt to parley with the outlaws, if any occasion arose. Gaines agreed tentatively. He knew of Harvey's long and honorable record as a labor leader, and was willing to try anything that offered a hope of success with a minimum of violence.

Shortly thereafter the first wave flushed another technician. He was on the far side of a rotor; they were almost on him before he was seen. He did not attempt to resist, although he was armed, and the incident would not have been worth recording, had he not been talking into a hush-a-phone which he had plugged into the telephone jack at the base of the rotor.

Gaines reached the group as the capture was being effected. He snatched at the soft rubber mask of the phone, jerking it away from the man's mouth so violently that he could feel the bone-conduction receiver grate between the man's teeth. The prisoner spat out a piece of broken tooth and glared, but ignored attempts to question him.

Swift as Gaines had been, it was highly probable that they had lost the advantage of surprise. It was necessary to assume that the prisoner had succeeded in reporting the attack going on beneath the ways. Word was passed down the line to proceed with increased caution.

GAINES' PESSIMISM was justified shortly. Riding toward them appeared a group of men, as yet several hundred feet away. There were at least a score, but their exact strength could not be determined, as they took advantage of the rotors for cover as they advanced. Harvey looked at Gaines, who nodded, and signaled the cadet captain to halt his forces.

Harvey went on ahead, unarmed, his hands held high above his head, and steering by balancing the weight of his body. The outlaw partly checked its speed uncertainly, and finally stopped. Harvey approached within a couple of rods of them and stopped likewise. One of them, apparently the

leader, spoke to him in sign language, to which he replied.

They were too far away, and the red light too uncertain, to follow the discussion. It continued for several minutes, then ensued a pause. The leader seemed uncertain what to do. One of his party rolled forward, returned his pistol to its holster, and conversed with the leader. The leader shook his head at the man's violent gestures.

The man renewed his argument, but met the same negative response. With a final disgusted wave of his hands, he desisted, drew his pistol, and shot at Harvey. Harvey grabbed at his middle and leaned forward. The man shot again; Harvey jerked, and slid to the ground.

The cadet captain beat Gaines to the draw. The killer looked up as the bullet hit him. He looked as if he were puzzled by some strange occurrence—being too freshly dead to be aware of it.

The cadets came in shooting. Although the first wave was outnumbered better than two to one, they were helped by the comparative demoralization of the enemy. The odds were nearly even after the first ragged volley. Less than thirty seconds after the first treacherous shot all of the insurgent party were dead, wounded, or under arrest. Gaines' losses were two dead —including the murder of Harvey—and two wounded.

Gaines modified his tactics to suit the changed conditions. Now that secrecy was gone, speed and striking power were of first importance. The second wave was directed to close in practically to the heels of the first. The third wave was brought up to within twenty-five yards of the second. These three waves were to ignore unarmed men, leaving them to be picked up by the fourth wave, but they were directed to shoot on sight any person carrying arms.

Gaines cautioned them to shoot to wound, rather than to kill, but he realized that his admonishment was almost impossible to obey. There would be killing. Well—he had not wanted it, but he felt that he had no choice. Any armed outlaw was a potential killer—he could not, in fairness to his own men, lay too many restrictions on them.

When the arrangements for the new marching order were completed, he signed the cadet captain to go ahead, and the first and second waves started off together at the top speed of which the tumblebugs were capable—not quite eighteen miles per hour. Gaines followed them.

He swerved to avoid Harvey's body, glancing involuntarily down as he did so. The face was set in a death mask of rugged beauty in which the strong fiber of the dead man's character was evident. Seeing this, Gaines did not regret so much his order to shoot, but the deep sense of loss of personal honor lay more heavily on him than before.

THEY PASSED several technicians during the next few minutes, but had no occasion to shoot. Gaines was beginning to feel somewhat hopeful of a reasonably bloodless victory, when he noticed a change in the pervading throb of machinery which penetrated even through the heavy antinoise pads of his helmet. He lifted an ear pad in time to hear the end of a rumbling diminuendo as the rotors and rollers slowed to rest.

The road was stopped.

He shouted to the cadet captain: "Halt your men!" His words echoed hollowly in the unreal silence.

The top of the reconnaissance car swung up as he turned and hurried to it. "Chief," the cadet within called out, "relay station calling you."

The girl in the visor screen gave way to Davidson as soon as she recognized Gaines' face.

"Chief," Davidson said at once, "Van Kleeck's calling you."

"Who stopped the road?"

"He did."

"Any other major change in the situation?"

"No—the road was practically empty when he stopped it."

"Good. Give me Van Kleeck."

The chief conspirator's face was livid with uncurbed anger when he identified Gaines. He burst into speech.

"So! You thought I was fooling, eh? What do you think now, Mr. Chief Engineer Gaines?"

Gaines fought down an impulse to tell him exactly what he thought, particularly about Van Kleeck. Everything about the short man's manner affected him like a squeaking slate pencil.

But he could not afford the luxury of speaking his mind. He strove to get just the proper tone into his voice which would soothe the other man's vanity. "I've got to admit that you've won this trick, Van—the road is stopped—but don't think I didn't take you seriously. I've watched you work too long to underrate you. I know you mean what you say."

Van Kleeck was pleased by the tribute, but tried not to show it. "Then why don't you get smart, and give up?" he demanded belligerently. "You can't win."

"Maybe not, Van, but you know I've got to try. Besides," he went on, "why can't I win? You said yourself that I could call on the whole United States army."

Van Kleeck grinned triumphantly. "You see that?" He held up a pear-shaped electric push button, attached to a long cord. "If I push that, it will blow a path right straight across the ways—blow it to kingdom come. And just for good measure, I'll take an ax, and wreck this control station before I leave."

Gaines wished whole-heartedly that he knew more about psychology. Well—he'd just have to do his best, and trust to horse sense to give him the right answers. "That's pretty drastic, Van, but I don't see how we can give up."

"No? You'd better have another think. If you force me to blow up the road, how about all the people that will be blown up along with it?"

Gaines thought furiously. He did not doubt that Van Kleeck would carry out his threat. His very phraseology, the childish petulance of "If you force me to do this—", betrayed the dangerous irrationality of his frame of mind. And such an explosion anywhere in the thickly populated Sacramento Sector would be likely to wreck one or more apartment houses, and would be certain to kill shopkeepers on the included segment of Strip 20, as well as chance passers-by. Van was absolutely right; he dare not risk the lives of bystanders who were not aware of the issue and had not consented to the hazard—even if the road never rolled again.

For that matter, he did not relish chancing major damage to the road itself—but it was the danger to innocent life which left him helpless.

A tune ran through his head:

"Hear them hum; watch them run. Oh, our work is never done—"

What to do? What to do?

"While you ride; while you glide; we are—"

This wasn't getting any place.

He turned back to the screen. "Look, Van, you don't want to blow up the road unless you have to, I'm sure. Neither do I. Suppose I come up to your headquarters, and we talk this thing over. Two reasonable men ought to be able to make a settlement."

Van Kleeck was suspicious. "Is this some sort of a trick?"

"How can it be? I'll come alone, and unarmed, just as fast as my car can get there."

"How about your men?"

"They will sit where they are until I'm back. You can put out observers to make sure of it."

Van Kleeck stalled for a moment, caught between the fear of a trap and the pleasure of having his erstwhile superior come to him to sue for terms. At last he grudgingly consented.

GAINES LEFT his instructions, and told Davidson what he intended to do. "If I'm not back within an hour, you're on your own, Dave."

"Be careful, chief."

"I will."

He evicted the cadet driver from the reconnaissance car and ran it down the ramp into the causeway, then headed north and gave it the gun. Now he would have a chance to collect his thoughts, even at two hundred miles per hour. Suppose he pulled off this trick—there would still have to be some changes made. Two lessons stood out like sore thumbs: First, the strips must be cross-connected with safety interlocks so that adjacent strips would slow down, or stop, if a strip's speed became dangerously different from those adjacent. No repetition of what happened on twenty!

But that was elementary, a mere mechanical detail. The real failure had been in men. Well, the psychological classification tests must be improved to insure that the roads employed only conscientious, reliable men. But hell's bells—that was just exactly

what the present classification tests were supposed to insure beyond question. To the best of his knowledge there had never been a failure from the improved Humm-Wadsworth-Burton method—not until today in the Sacramento Sector. How had Van Kleeck gotten one whole sector of temperament-classified men to revolt?

It didn't make sense.

Personnel did not behave erratically without a reason. One man might be unpredictable, but in large numbers personnel were as dependable as machines, or figures. They could be measured, examined, classified. His inner eye automatically pictured the personnel office, with its rows of filing cabinets, its clerks—He'd got it! He'd got it! Van Kleeck, as chief deputy, was ex officio *personnel officer for the entire road*!

It was the only solution that covered all the facts. The personnel officer alone had the perfect opportunity to pick out all the bad apples and concentrate them in one barrel. Gaines was convinced beyond any reasonable doubt that there had been skullduggery, perhaps for years, with the temperament classification tests, and that Van Kleeck had deliberately transferred the kind of men he needed to one sector, after falsifying their records.

And that taught another lesson—tighter tests for officers, and no officer to be trusted with classification and assignment without close supervision and inspection. Even he, Gaines, should be watched in that respect. *Qui custodiet ipsos custodes?* Who will guard those selfsame guardians? Latin might be obsolete, but these old Romans weren't dummies.

He at last knew wherein he had failed, and he derived melancholy pleasure from the knowledge. Supervision and inspection, check and re-check, was the answer. It would be cumbersome and inefficient, but it seemed that adequate safeguards always involved some loss of efficiency.

He should not have intrusted so much authority to Van Kleeck without knowing more about him. He still should know more about him—He touched the emergency-stop button, and brought the car to a dizzying halt. "Relay station! See if you can raise my office."

Dolores' face looked out from the screen. "You're still there—good!" he told her. "I was afraid you'd gone home."

"I came back, Mr. Gaines."

"Good girl. Get me Van Kleeck's personal file jacket. I want to see his classification record."

She was back with it in exceptionally short order, and read from it the symbols and percentages. He nodded repeatedly as the data checked his hunches: Masked introvert—inferiority complex. It checked.

"'Comment of the board':" she read. "'In spite of the slight potential instability shown by maxima A and D on the consolidated profile curve, the board is convinced that this officer is, nevertheless, fitted for duty. He has an exceptionally fine record, and is especially adept in handling men. He is, therefore, recommended for retention and promotion.'"

"That's all, Dolores. Thanks."

"Yes, Mr. Gaines."

"I'm off for a showdown. Keep your fingers crossed."

"But, Mr. Gaines—" Back in Fresno, Dolores stared wide-eyed at an empty screen.

"TAKE me to Mr. Van Kleeck!"

The man addressed took his gun out of Gaines' ribs—reluctantly, Gaines thought—and indicated that the chief engineer should precede him up the stairs. Gaines climbed out of the car, and complied.

Van Kleeck had set himself up in the sector control room proper, rather than the administrative office. With him were half a dozen men, all armed.

"Good evening, Director Van Kleeck." The little man swelled visibly at Gaines' acknowledgment of his assumed rank.

"We don't go in much around here for titles," he said, with ostentatious casualness. "Just call me Van. Sit down, Gaines."

Gaines did so. It was necessary to get those other men out. He looked at them with an expression of bored amusement. "Can't you handle one unarmed man by yourself, Van? Or don't the Functionalists trust each other?"

Van Kleeck's face showed his annoyance, but Gaines' smile was undaunted. Finally the smaller man picked up a pistol from his desk, and motioned toward the door. "Get out, you guys."

"But, Van—"

"Get out, I said!"

When they were alone, Van Kleeck

picked up the electric push button which Gaines had seen in the visor screen, and pointed his pistol at his former chief. "O. K.," he growled, "try any funny stuff, and off it goes ! What's your proposition ?"

Gaines' irritating smile grew broader. Van Kleeck scowled. "What's so damn funny ?" he said.

Gaines granted him an answer. "You are, Van — honest, this is rich. You start a Functionalist revolution, and the only function you can think of to perform is to blow up the road that justifies your title. Tell me," he went on, "what is it you are so scared of ?"

"I am not afraid !"

"Not afraid ? You ? Sitting there, ready to commit hara-kiri with that toy push button, and you tell me that you aren't afraid. If your buddies knew how near you are to throwing away what they've fought for, they'd shoot you in a second. You're afraid of them, too, aren't you ?"

Van Kleeck thrust the push button away from him, and stood up. "I am not afraid !" he shouted, and came around the desk toward Gaines.

Gaines sat where he was, and laughed. "But you are ! You're afraid of me, this minute. You're afraid I'll have you on the carpet for the way you do your job. You're afraid the cadets won't salute you. You're afraid they are laughing behind your back. You're afraid of using the wrong fork at dinner. You're afraid people are looking at you—and you are afraid that they won't notice you."

"I am not!" he protested. "You . . . you dirty, stuck-up snob ! Just because you went to a high-hat school you think you're better than anybody." He choked, and became incoherent, fighting to keep back tears of rage. "You, and your nasty little cadets—"

Gaines eyed him cautiously. The weakness in the man's character was evident now—he wondered why he had not seen it before. He recalled how ungracious Van Kleeck had been one time when he had offered to help him with an intricate piece of figuring.

The problem now was to play on his weakness, to keep him so pre-occupied that he would not remember the peril-laden push button. He must be caused to center the venom of his twisted outlook on Gaines, to the exclusion of every other thought.

But he must not goad him too carelessly, or a shot from across the room might put an end to Gaines, and to any chance of avoiding a bloody, wasteful struggle for control of the road.

GAINES chuckled. "Van," he said, "you are a pathetic little shrimp. That was a dead giveaway. I understand you perfectly—you're a third-rater, Van, and all your life you've been afraid that someone would see through you, and send you back to the foot of the class. Director—*pfui* ! If you are the best the Functionalists can offer, we can afford to ignore them—they'll fold up from their own rotten inefficiency." He swung around in his chair, deliberately turning his back on Van Kleeck and his gun.

Van Kleeck advanced on his tormentor, halted a few feet away, and shouted: "You . . . I'll show you . . . I'll put a bullet in you ; that's what I'll do !"

Gaines swung back around, got up, and walked steadily toward him. "Put that popgun down before you hurt yourself."

Van Kleeck retreated a step. "Don't you come near me !" he screamed. "Don't you come near me . . . or I'll shoot you . . . see if I don't !"

"This is it," thought Gaines, and dived.

The pistol went off alongside his ear. Well, that one didn't get him. They were on the floor. Van Kleeck was hard to hold, for a little man. Where was the gun ? There ! He had it. He broke away.

Van Kleeck did not get up. He lay sprawled on the floor, tears streaming out of his closed eyes, blubbering like a frustrated child.

Gaines looked at him with something like compassion in his eyes, and hit him carefully behind the ear with the butt of the pistol. He walked over to the door, and listened for a moment, then locked it cautiously.

The cord from the push button led to the control board. He examined the hook-up, and disconnected it carefully. That done, he turned to the televisor at the control desk, and called Fresno.

"O. K., Dave," he said, "let 'em attack now—and for the love of Pete, hurry !" Then he cleared the screen, not wishing his watch officer to see how he was shaking.

BACK in Fresno the next morning Gaines paced around the main control room with a fair degree of contentment in his heart. The roads were rolling—before long they would be up to speed again. It had been a long night. Every engineer, every available cadet, had been needed to make the inch-by-inch inspection of Sacramento Sector which he had required. Then they had to cross-connect around two wrecked sub-sector control boards. But the roads were rolling—he could feel their rhythm up through the floor.

He stopped beside a haggard, stubbly-bearded man. "Why don't you go home, Dave?" he asked. "McPherson can carry on from here."

"How about yourself, chief? You don't look like a June bride."

"Oh, I'll catch a nap in my office after a bit. I called my wife, and told her I couldn't make it. She's coming down here to meet me."

"Was she sore?"

"Not very. You know how women are." He turned back to the instrument board, and watched the clicking busybodies assembling the data from six sectors. San Diego Circle, Angeles Sector, Bakersfield Sector, Fresno Sector, Stockton—Stockton? Stockton! Good grief—Blekinsop! He had left a cabinet minister of Australia cooling his heels in the Stockton office all night long!

He started for the door, while calling over his shoulder: "Dave, will you order a car for me? Make it a fast one!" He was across the hall, and had his head inside his private office before Davidson could acknowledge the order.

"Dolores!"

"Yes, Mr. Gaines."

"Call my wife, and tell her I had to go to Stockton. If she's already left home, just have her wait here. And, Dolores—"

"Yes, Mr. Gaines?"

"Calm her down."

She bit her lip, but her face was impassive. "Yes, Mr. Gaines."

"That's a good girl." He was out and started down the stairway. When he reached road level, the sight of the rolling strips warmed him inside and made him feel almost cheerful.

He strode briskly way toward a door marked, "Access Down," whistling softly to himself. He opened the door, and the rumbling, roaring rhythm from down inside seemed to pick up the tune even as it drowned out the sound of his whistling.

"Hie! Hie! Hee!
The rotor men are we—
Check off your sectors loud and strong!
ONE! TWO! THREE!
Anywhere you go
You are bound to know
That your roadways go rolling along!"

DEPUTY CORRESPONDENT

By Harl Vincent

Venusian are extreme good as correspondent—particularly when the Earthmen don't quite know who's at war with which!

Port of Callisto
Satellite Callisto
By Planet Jupiter
December 25, 2151

Terrestrial Press Association
City of Greater New York
United North America
Planet Terra

RESPECTED GENTLEMEN:

In above manner I was instructed to address you and advise, with his authorizing, I undertake duties of Steve Bowdoin, your special correspondent until very recent date. Gladly I do this extra to my work with Saffron City *Chronicle*, which, surely you are aware, is foremost Venusian daily. You have my permitting to use this copy at regular space rates or suggest any differing arrangement you desire. Stephen Bowdoin is out of picture and I elucidate reason hereinafter.

Being experienced *Chronicle* reporter, taking also four years night study American language in School of Terrestrial Knowledge, Saffron City, likewise history and literature of same, I am superbly qualified as deputy of Bowdoin. I proceed:

I have not found copies of any news Steve has sent you whatever. Perhaps, then, I do best to start at commencing. Which, you must cognize, was when Triplanetary Expedition for Callistonian Exploration and Research reached this ill-omened body. Not mine to say whether our good or bad fortune we three representatives of power of press were included. Suffice it we were. Lak Tjurned, for Risapar *News* of Mars, Bowdoin and myself (use immediately for by-line my name, Serle Tummin, without need turning to end of copy) were three excited correspondents. We have been more so as time progressed until as I inscribe.

After ten terrestrial years preparing for event, it is deeply regrettable confusion should result. Blame lies not with expedition, readers will learn, but with conditions so vastly distant as Terra. I write strictly neutrality in all respects. Not as Venusian or partisan, but as observer and chronicler with disinterest. My emotion is spent.

Port of Callisto welcomed us jubilantly. Though no more than mean trading post at edge of Callistonian jungle. We saw here radio station, fuel pit, repair shop, house named "Barngril" for purchase of food and spirituous beverage. Likewise poor native huts. A few men of our three planets, a few natives, no more. Truly, we expected no more. Our first object of exploration was this Barngril.

"I'm buying, Serle, old man," were Bowdoin's first words inside. I am not old whatever, but forty Venusian years which are twenty-five terrestrial. Bowdoin speaks idiom not learned in our good American School but of understanding. "What'll it be, old man, Martian chulco?"

I nodded assent. Indeed, my throat was parched after twenty days on that stuffy leased ship from Port of Mars. All others of expedition entering Barngril suddenly merry and encouraging by glistening mahogany and glassware. Not to mention railing of brass for feet.

Natives gathered around as product of Martian cactus lubricated arid throats. These being yellow-furred bipeds, color photos herewith, with round mouths for eating only. Stalks on which eyes will be seen at end likewise for communicating of small intelligence owners possess. Cold as is this moon, fur highly approved. As is chulco.

Motley crew of *Pioneer*, our vessel, now entered Barngril, noisily demanding libations. Then music from Mars broadcasters commencing. Crew, mostly Terrestrians of widely varying extracting, relax strenuously. Enjoying selves hugely until music interrupted by news flashes of Terra. This surely bringing swift attentions from we three representatives of power of press. Steve Bowdoin being highly incensed immediately. Why ?—question of reader will be. Only because nations of Terra then declaring latest one of many wars "to end all war."

Indeed, it was at once as if war was declaring in Barngril.

IN MY LONG studying of Terra in American School I am not fully understanding reason maps always changing. With boundaries moved this way and that so frequently, so much like Venusian game of thousand moving squares. Lak Tjurned, having not as much learning of Terra as I, even greatlier confused. We two withdrew our company from Steve, who began vociferating with crew of *Pioneer* as with Terrestrian scientists. Eight from Terra all of differing national persuasion, which is seeming uniqueness of Terra in Solar System. Natives likewise now withdrawing to opposite side of Barngril. Voice of radio useless.

Man who purveys chulco across mahogany now professed self Terrestrial, although more like long-armed Martian gorilla. Proclaiming loudly name of Mike, he entered raucous debating. With retreating natives to freezing outside air went Lak Tjurned, scientists from Venus and Mars, likewise myself. Natives continued retreat across clearing to disappearing in jungles. We of expedition disappeared inside *Pioneer*.

Eating here in quiet was preferable to Barngril. Anxiety of scientists for commencing exploration was only discussion. Much was to be learned of Callisto during activity of Red Spot of Jupiter, they declared. Delay extremely regrettable.

Zyrkenj and Nejney, from Risapar Academy of Mars, were according fully with Venusians, Limmus and Thiammi, here by financing of Saffron City *Chronicle*, likewise of Solar System *Geographic*. Such is power of press. Prideful, Lak Tjurned and myself agreeing fully with scientists. Agreed to return to Barngril, making effort zealously to extract Terrestrian scientists and Steve Bowdoin from bickerings.

We enjoyed immediately success with Steve, who, our sole North American, was proclaiming strictly neutrality in this vastly distant echoing of new conflict to make Terra safe for something he did not now remember. Forrester and von Teufel, those Terrestrian scientists, were impossible of persuasion to return to *Pioneer*, being engaged in convincing large and hairy Scandinavian and Eurasian of crew adversely to hereditary allegiance. Question of Nordic supremacy, religious freedom, and Yellow Peril so hopelessly involved starting a Mediterranean, a Pan-German, and one Australian of crew actually physical combatting to accompaniment of loud retraction from mad radio of earlier announcement of allying nationalities. Before violently commencing combat accomplish smashing glassware, it was learned participants no longer enemies but of new alliance. By now our Chinese valver and Jap galley boy asleep, embraced lovingly in one rear booth of Barngril, unaware they are again enemies.

"I'm getting out of here," growled Steve. When I endeavored to steady him he turned amazingly to von Teufel, the scientist. "And if you think North America is going to watch any Pan-Germanic vandals overrun Terra, you're nuts !"

Von Teufel, florid of countenance, tugging his enormous mustache, shouted : "*Schwein !* We shall see what—"

That was when your erstwhile correspondent smote von Teufel and was taken from Barngril by his two colleagues of power of press to frigid outer air. Von Teufel, lying with head on railing of brass, unable to make reprisal. Lak Tjurned and I, busy with that great red-haired hulk Bowdoin, being not certain that new retracton might issue from radio, moved speedily to *Pioneer* with our rapidly tiring companion.

With bunk in same cabin, I was happily

"—Much fear good friend Steve are permanently gone with mysterious pyramid—"

able to hear Steve quickly snoring, myself praying all best for tomorrow as light extinguished.

NEXT DAYLIGHT dawned on much illness in *Pioneer*.

"Get me the doctor," groaned Bowdoin, awakening.

Aware of what must follow, I betook me to Barngril for breakfast. Under ugly sky with gigantic Jupiter glowing purple around angry Red Spot where arm could almost reach, I was feeling not too well myself. Across mahogany, Mike, appearing none worse for that war echo last night, prepared special concoctions performing miracles.

Then it was that Forrester made speech sensibly. All gave thoughtful attention.

"We must remember," Forrester orated, "that this is a serious scientific expedition. Of interplanetary importance. We should, therefore, not think in terms of the war on Terra. Those who could and would serve their native lands cannot return in any event. Those from Mars and Venus have no interest whatever except in the success of this venture. We should perform our obligations to the Triplanetary Academy of Science to the best of our ability, forgetting the differences now disrupting the one planet, Terra. I, for one, am willing and ready to bend every effort to the task ahead and forget all thoughts of national differences. To obviate further brawling, it is my suggestion we divide into three groups temporarily. We have three planes, making such a course logical and simple. Venusians and Martians are naturally neutral in this war of Terra. So is Bowdoin, the North American, though I must admit he has exhibited a belligerent attitude at times. That is beside the point. He should be in the group comprising, otherwise, Martians and Venusians. As likewise should the sole Scandinavian of our crew. That leaves the adherents of the two warring groups on Earth. I shall take it upon myself to head the second group and suggest that von Teufel, whose war views are diametrically opposed to mine, head the third. The rest may join with one or the other of us as their feelings dictate. Is this agreeable to all?"

Which was fine speech, excellent example of English from which American language originated. It likewise met approval.

In midst of acclaim, one terrific detonation occurred outside, rocking Barngril with utmost violence, hurling glassware from shelves shattering. Likewise flinging terrified native imbibers into heaps of yellow fur. Mike, spouting most luridly with cursing, ran to door to collide heavily with many of expedition attempting simultaneous egress. Portions of interplanetary radio station rained indiscriminately from this somber sky of Callisto. After which, in awed silencing, it became increasingly evident no more radio station was existing on Callisto. Instead, there was crater fringed with debris.

Behind me one snarling ugly voice proclaimed: "Sabotage! Only such rotten butchers and ravagers as Pan-Germanics would—"

This accusation was interrupted by sound of violent blow of fist. Steve Bowdoin, miraculously recovered from indisposition, put swiftly a stop to that fight. Steve is large of size and voice. Strangely, one Pan-German remained on floor in coma.

For first time spoke Thiammi of Venus: "One third radio station was property of my world, one third of Mars. Therefore, we of Venus and Mars should have more complaint than any. We resign ourselves to this destruction which opportunely causes cessation of disturbing news from Terra. If word sabotage applies, it is most commendable word indeed."

Thiammi, besides being great scientist of Venus, has been instructor in our American School. I was proud of his speech in this American language. Likewise, it brought accord again instantly.

It is significant no investigation was made of explosion, is my personal belief. (This not for publication.)

WE OF VENUS are of lesser physical dimension and power than those of Mars and Terra, but our mentality is considerable. At once I knew we three of press could not occupy that ship of neutrals. Only one third of all news would then accrue jointly, which is wrong. There are varieties of neutrality, some strictly so, some for armed isolation, some vigorously sympathizing with one actual belligerent, et cetera. Tjurned and I being of this strictly variety, I thought it expedient we leave Steve

Bowdoin with neutrals and each occupy one other ship, thus accumulating differing information. My suggestion likewise won acclaim, confirming my own perspicacity.

Regardless, we made ready those three airships. One was very superior Martian gyroplane, our second a highly powered stratoplane of Terra, third our own unexcelled Venusian product. That first one carried all neutrals including Steve and that Scandinavian. Our Venusian plane fell to Forrester's party and Lak Tjurned. I chose stratoplane, not, you cognize, because of lacking faith in Venusian production, but because of mistrusting von Teufel. He required watching, perhaps.

Loaded with supplies, arms, powering equipment, we started on that initial satellite-bound flight. This being first expedition carrying airships to Callisto, we were first to penetrate to any great distance of its interior.

Callisto is world of smooth contour, unbroken by canals such as of Mars, not spouting geysers of steam with resulting clouds as on Venus, neither flaunting mountain peaks skyward. Like Terra, it has large seas. Islands are many, showing thickness of jungle surprising for low mean temperature. Native settlements few and far between.

Most of this day spent in observation from air until appearing of incredibly Gargantuan Jupiter as if to plunge in sea and ruin satellite, our enfeebled sun weirdly lighting opposing mists. Then we sighted that island of mystery never before reported.

I was in control cabin of stratoplane with Turkish navigator who suddenly ululated: "By the horns of the crescent—a pyramid!"

One enormous pile of rock centered precisely in center of this island. Although not pointed at top as are representations of Egyptian pyramids in American School. Still that structure was gigantic, rising almost to our flight level and covering half this island. Encircling it were many dwelling places likewise of stone, in rows of orderliness unbelievable.

Von Teufel muttered gutturally in rasping tongue as he saw swarms of natives in that area about this pyramid. Not like natives at Port of Callisto or other islands. More like really human. And they wore clothing! It was more incomprehensible when they prostrated on stone pavements after casting eyes aloft to our three circling planes.

Ahead, Forrester signaled for a landing, whereupon we spiraled down to great open space at pyramid base. Steve Bowdoin leaped from neutrality plane before it stopped rolling. Thus your former representative was first to be greeted by civilization never before reported. Thousands arose from prostration to acclaim him a god!

Lak Tjurned, von Teufel, Forrester, Limmus, myself and the rest rushed forward, disregarded. Chants arose and procession made commencing with Steve in honored midst. Straight toward broad temple gates at pyramid base streamed native rabble, we others trailing helplessly.

Steve Bowdoin, borne now upon heaving shoulders, gazed back with laughter. Seeing me, he shouted: "How do you like this, old man?"

I could not reply for violence of hands laid upon my person. I remember only frosty green eyes of that monster having steel grasp. Nothing thereafter.

WHEN NEXT my eyes opened, not one iota of visual sense did I have. My shouts of alarm echoed in my ears. I sneezed and dust of countless ages swirled about me amidst darkness unthinkable. No faintest sound save my own hoarse breathing. Could this be death? No; far worse. Appalling realization smote me I was entombed in heart of pyramid. I sat disconsolate in thick dust of floor, sneezing, abandoning hope.

Many hours I suffered thus, alternately squatting hopelessly and rising to pace narrow confines of this living tomb. Always this dry, choking dust; always I sneezed and coughed. I became parched with thirst, craving food acutely. Finally there was sound, then light through opening of stone wall. I observed flaming red hair of Steve Bowdoin above lengthy purple robe.

He greeted me as I stumbled out, blinking. "Sorry I couldn't get to you sooner, Serle. Come along with me now, pronto."

Never had odd idiom sounded lovelier. He handed me one large luscious globular fruit, assuaging both hunger and thirst.

"What means this outrage?" I inquired, between dripping bites.

"Outrage, nothing! Serle, this is the biggest thing in the Solar System. Maybe in the Universe. Listen: they think I'm a god they've waited for since antiquity. And I let them. There's a big scoop in this and I want you to handle it. That's why I came for you now."

We traversed long corridor hewn from solid rock. Brilliant lamp in hand of Steve providing light of white intensity without heat. He shrugged when I inquired about that, saying merely: "Wait."

Soon we stopped at spot of wall where cracks in stone appear. A sharp word spat against stone by Steve caused large section of rock to swing back miraculously. I could make no sense of it whatever. From darkness emerged Limmus, blinking and sneezing in familiar manner. For Limmus, Steve likewise had a fruit.

At length we arrive at Brobdingnagian cavern containing multitude of giant machines. In heart of pyramid on satellite Callisto! How could these things be?—reader will ask. Following is elucidation.

"Where are others of our party?" Limmus inquired.

"Never mind those dimwits," spoke up Steve. "This thing's so big I don't trust them. Only you two. Limmus, I've got you in on it because I need certain scientific help. You, Serle, because I want you to report to my employers after I'm gone."

"Gone!" This was first intimation of what was to follow.

"Yes, gone. But, look; I want you to see something." Bowdoin pranced to central draped pedestal, drew off heavy cloth of purple.

A transparent casket was revealed. In that interior lay form of human being, male. Rugged features, weathered skin, red hair, all identical counterpart of American correspondent. Limmus opened wide his orange eyes and his skin went white as mobile fungi of Venusian swamp.

"Looks like me, doesn't it?" Steve Bowdoin grinned in inimitable manner. "That's why they think I'm their god."

"Why then do they imprison us?" This with dignity from Limmus.

"A part of their legend, too. The god was to come out of the air like a bird at the appointed time and was to have prisoners along for a sacrifice to the Sun. I'm supposed to sacrifice you all tomorrow."

"But you will not do so?" I asked in trepidation.

"Not if I can help it. But first you'll have to help me." He covered this crystal-inclosed form carefully with that purple cloth.

Steve led us to huge machine having three black panels and myriad crystal levers. He inserted a golden key in slot, whereupon humming of great live forces arose within. Those panels lighted to roseate luminosity. Pictures appeared thereon. Accompanying thoughts impressed on my brain in stunning clarity with conviction of truth.

Dazed when machine discontinued, I made valiant effort collecting my faculties. Understanding but one fraction of communications.

"That," said Steve, "is the true history of ancient Mu."

DIMLY I recalled legend of old American book, unable to connect this with Callisto whatever.

Limmus was better informed. "The lost continent of your Pacific Ocean?" he interrogated. "What has that to do with this remote place?"

"This *is* Mu," averred Bowdoin. "What's left of it. For two hundred centuries or more, this cavern has remained as it was then. Sealed and preserved by rare gases until this day of my coming. The god who is to return these last of the children of Mu to their former habitat in the Pacific. A dream of unnumbered ages."

The hairless round head of Limmus creased deeply in high frown. "You believe you are this god?" he inquired.

Steve's laugh echoed in arches overhead. "I don't. I think it's coincidence that I have a phiz and a mop like his, that's all. Yet I sort of feel obligated. Not to them so much. To Terra. You see, the Lemurians were warriors as well as scientists. Ancient Mu was colonizing Terra, conquering all as they swept across South America and the Amazon Sea, which then existed, to Atlantis and across from there to the Mediterranean. Twenty thousand years ago, they knew of the cataclysm that was to break up Earth's crust and submerge both Mu and Atlantis. They prepared by building many pyramids, those in Mexico and Egypt still remaining on Terra and still

mysteries. This pyramid here, this entire island, was once the cultural, religious and scientific center of Mu. When Mu broke up, forces incorporated in this very cluster of mechanisms surrounded us hurled this entire island portion and its remaining population through space. They landed it here, protected in the then sealed pyramid. Now they look to me to take them back. All their former science they've forgotten, though they still use atomic power and light without understanding it. But there are still greater potentialities only to be revealed to their god—alias yours truly."

I was amazed at knowledge Steve's long speech betrayed. Why did he need Limmus? Why me?

"You speak of forces more potent than atomic disruption," said our Venusian scientist. "Impossible."

"I didn't say more potent," returned Steve. "Better adapted to certain things, is all. More obscure. That's why I want your help."

Your amazing former correspondent indicated two gigantic spheres from which cables led into high arches of chamber.

"This," he said—pointing out that one of green color—"collects electromagnetic energies from sun spots. There's plenty about sun spots none of you know, Limmus. You know they occur in cycles about every eleven years and that they affect radio transmission. That's about all. But this sphere collects and uses these energies. There's a formula at the base you ought to be able to solve for me. The same with the red sphere, only it collects and utilizes widely differing but equally potent energies from the Red Spot of Jupiter. I want to know how much capacity to count on and exactly how it's utilized to pick up this island out of the Callistonian sea and make a spaceship out of it. So get busy with your figures, Limmus, will you?"

"You intend then returning this island to Terra?" asked Limmus.

"I don't know. Not yet, anyway." Bowdoin showed him two tablets covered with ancient etchings. "Come on, Serle, you and I'll free the others while Limmus works at it."

Steve then handed me his Press Association card, after scribbling my deputization thereon.

WE PADDED through corridors thereafter, releasing members of expedition. Sick, scared, angry, argumentative, Steve managed finally impressing upon all necessity of haste. Planes were ready and populace sleeping soundly under radiated potions from this place, he assured those fools who retained impulse for fighting impossibility of odds.

Forrester promised waiting for Limmus and myself, after which I returned with Steve where scientist of Venus still perspiring nobly.

He told Steve with excitement unusual for Venusian: "I have formulae solved for you, Stephen. Nature and method of utilization of forces. Calculation of directional lines must be made on celestial chart by you."

I listened to much conversation between those two, gaining little. Lines of force between solar bodies could be utilized like snapping of bowstring, I gathered. Entire secret of operation being known only to Steve in this role of Lemurian god he is necessarily assuming.

"I've got it now," that Earthman exulted. "I'll bring in these Callistonian children of Mu, seal the passages of the pyramid, and we go away from here. Now scram, you two. They'll be madder than hell if I keep them under too long."

"Under!" I exclaimed. "Scr—"

"Yes, under. Asleep." Steve pointed out one whirring machine of many shimmering disks making blur brilliant to sight. "I've had to keep them under this mass-hypnotism gadget that was invented you know how long ago. So the rest of you could escape. Lucky it affects only their thought-wave patterns, not ours. And scram I meant, too; beat it. Both of you. Good-by."

Then Steve handed me a helmet affair with high dome and projecting metal rods. "A telepath," he explained. "Preserved through the ages. Wear it and communicate with me before I leave. I'll get final news to you that way. Maybe even—afterwards."

LATER, in plane beside von Teufel, I tried telepath, hoping Steve already attempting communicating. A knob thereon, with turning this way and so, produced no result. Von Teufel laughed nastily, ridicul-

ing. Hereafter, I resolved, I should say no more to these dimwits, as Steve designated them. I wore this helmet whatever, hating von Teufel's kind.

Soon helmet became living with thought of Bowdoin. Most eerie sensation, like speech and yet not. No sound, only Steve's distinctive idiom of speech became active thinking alive in my brain.

"You're a pretty good scout, Serle," he was telling me, as plane sped over jungle and sea, "and I didn't want to say too much in front of Limmus. Not that he isn't a damn good scientist, you understand. But here's the real low-down on this plan of mine, and you can put it in your dispatch to Terrestrial Press. Wait—high priest coming—"

I thought back at him mightily, but no result forthcoming for long minutes. Then: "Some ceremony, Serle! Sort of war dance around me. But the helmet stays on; they think I'm communicating with Old Sol himself. Ever read Kipling? 'The Man Who Would Be King'? I feel like that now. Hope I don't end like that guy of Kipling's. Getting me?"

Concentrating thought powerfully at him I convey back: "Indeed, yes, Steve. Proceed."

He proceeded: "Well, here's what I want you to put in your copy. I'm going into this Lemurian thing for one reason. No, two. There's a raft of weapons and secrets in this inner chamber that are stupendous. If they ever got loose among certain Terrestrians, it'd be just too bad. I'm going to see they don't get in the wrong hands on Terra. These childish children of Mu think they're returning to the green Pacific, but they are like hell. At least not right now. I'm taking them somewhere as far from Terra as I can get them. Why, if I landed this superarsenal in the Pacific, it'd be overrun with spies in no time. The wrong ones would get the secrets of these weapons. No, we're going for a long ride. Alpha Centauri, maybe. But—I'm keeping in touch with Terra through this helmet. Try it, Serle: you can tune in on thought-wave components of the planetary broadcasts. Distance doesn't make any difference with thought waves. And if I learn that the Pan-Geurasian forces of dictatorship, intolerance and butchery are getting the upper hand in Terra, I'm turning around and coming back and turn some of these energies on them and rid Terra of the scourge for keeps. Get that, old man? And tell them— Hold everything! More ceremony. Signing off."

Thoughts hurled back Steveward brought nothing in results. Then I saw Port of Callisto heaving up into vision. Jupiter thrusting vast red-and-blue sphere over horizon, although our sun not yet risen.

Next thing we are all in Barngril, demanding chulco and indulging much conversation.

MANY of furry natives in place and, examining those antennae that support their goggling eyes and serve for own thought communicating as well, I derive idea of great brilliance. Perhaps my helmet may allow interchange of thought with these near-humans. To their joy and mine, helmet operated in manner suspected.

Soon I was engaged with furry little native of seeming moderately intelligence. When I flashed thought of that island of pyramid he evinced abject terror. Legends of furry folk checked with coming of that island in blaze of glory from heavens before time began. Likewise with myth of anticipated leaving. This fur ball told of great former civilization of own kind oppressed by Lemurians of decimation down through ages, of slavery unspeakable, of bitter warfare. Horrific.

By now, crew of *Pioneer* were again hilarious and adventuresome. One Eurasian of Terra, huge as those green-eyed Lemurian offspring, approached me where I lounged at mahogany with native. Bellowing strange talk, this one snatched helmet from my head, adjusting it to his own, whereupon all natives retreated to space beside outer door.

This savage of Terra fiddled with knob of helmet with glazed eyes both regarding own nose simultaneously, such concentrated regard producing crossing lines of vision of optica with laughable result.

Suddenly this barbarian squealed: "*Himmel!* This *is* radio. The Pan-Geurasian Alliance has traitors. *Schwein!*"

This madman cast that helmet to floor and skidded along mahogany to smash into sole Brazilian of crew. Confusion ensued immediately, bringing Mike across

that mahogany in one most agile leap high jumping. When I made reaching downward to save thought helmet, von Teufel jumped on my hand with rough hobnails. I spouted rage, blowing on those injured fingers as he adjusted this cap of antiquity. His beefy face registered doubt, then amazement.

"*Rechtig!*" he bellowed. "But our fatherland will triumph regardless. *Uber alles!*" He rushed Forrester, that British scientist.

I snatched this helmet as Mike produced sizable bludgeon fashioned after pattern of wooden implements used in American ball-game sports. That was signal for cessation of hostilities and swift setting up of fresh chulco by this purveyor called Mike. Peace declaration of Mike produced mollification, also coma of von Teufel and that Eurasian.

Meanwhile was coming fresh news from Steve. "All ready for the take-off, Serle, old man," he conveyed. "We're snapping off for outer space. Stand by for further announcement."

Desperately I attempted conveying to Steve news of latest development in war to end all war, thinking it might alter his plan. To no avail whatever. But I went out into false dawn of Callisto nevertheless, failing to observe Thiammi at my swiftly moving heels.

As related, monstrous Jupiter was rising before we reached Barngril. It was now largest hemisphere capable of imagining, filling sky, casting strong weirdly shadows over jungles. Red Spot flaming with threatening fires. I looked toward direction of island of children of Mu, desperately endeavoring to call Steve. Again no result.

One most brilliant pencil of red flung out from horizon to Callisto toward Red Spot, causing dazzling splash of whiteness on reaching. One bright edge of sun peeped immediately over horizon on other quadrant. After which it occurred. Into infinity, leaping up and tapering off from this moon of Jupiter, flung one blinding column of rainbow light. It flickered off, leaving eyes dazzled and unseeing, heart pounding. Ominous silence oppressed, as if forces of nature about to collapse all Universe. The violent shaking of ground hurled me to rocky soil so forcefully I was not for some time cognizant of surroundings. Crashes of sound such as never before heard shattered eardrums. Waves of air compression tortured my aching body. Effect was terrifically awful. Momentarily I anticipated cessation of all knowledge and complete dissolution. Then, at length, the storm had passed. So had Steve Bowdoin and those children of Mu with island.

Staggering to upright as ground stopped swaying, I saw all from *Pioneer*, also natives, outside of Barngril, those humans' mouths in same shape of letter "o" as are permanently natives'. To my astonishment, I was laughing with utmost boisterousness. Thiammi was stamping down and up on my helmet while smashing glass spattered outwardly from its delicate mechanisms.

My laughter discontinued abruptly. "Now I know definitely who exploded radio station," I hissed at Thiammi.

He placed finger to his lips, glaring first, afterward pulling up corners of mouth in Venusian smile of triumph. "At least there will be no more news of war of Terra on *this* expedition," he gloated. "I will buy chulco, Serle Tummin."

We trouped inside with others.

(Preceding dialogue not for publication.)

THUS ENDS my first, I hope, of many official dispatches to your excellent association. I forward it, with many inclosures of color photos, via planet Mars by small supply ship arriving from there tomorrow. And likewise inclosed is photostat copy of my deputization by poor Stephen Bowdoin to his former work. I miss that correspondent enormously.

It is most regrettable we have no means of communicating further with that brave one who made commencing of journey into unknown. Pray he survived. Personally, I believe him sort who must succeed. For which reason, I trust this dispatch will serve as deterrent to those despoilers of Terra. Firmly I am convinced Bowdoin will keep watch by means of helmet he has not destroyed, I hope, and keep word he gave as to administering justice. We have no news here whatever.

Meanwhile, exploration continues with minimum disturbance. We flew yesterday across former site of island of pyramid, finding naught save expanse of rippling waters.

Further dispatches will follow in sequence. Interplanetary check in payment of my services should be made out as below.

Your servant faithfully,

SERLE TUMMIN.

P.S.: Observing Terrestrial date hereon, I convey Merry Xmas greeting. Peace on Earth, et cetera, et cetera. S. T.

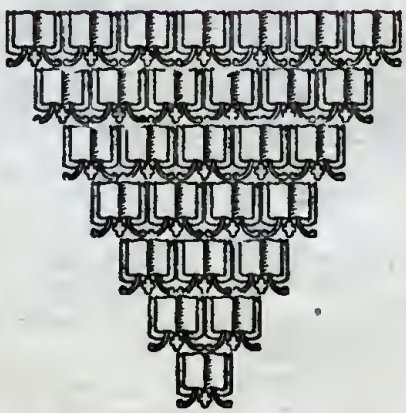
SPACEOGRAM

NY UNA TERRA CH 113 FEB 12 52
NL MARS VIA PACKET

SERLE TUMMIN TERRESTRIAL PRESS
CORRESPONDENT
PORT OF CALLISTO

YOUR COPY WENT BIG IN SUNDAY SUPPLEMENT STOP INCLOSED CHECK SERVICES TO DATE STOP YOUR BELATED GREETING ACKNOWLEDGED STOP CONCERN FOR BOWDOIN UNNECESSARY STOP ISLAND ARRIVED TERRA BLASTING PAN GEURASIAN MENACE OUT OF EXISTENCE DELIVERING TERRA FROM INTOLERANCE OPPRESSION HATRED CONFUSION BRUTALITY STOP ISLAND NOW PEACEFULLY ESTABLISHED IN ANCIENT LOCATION STOP BOWDOIN PRESIDENT REPUBLIC OF NEW MU STOP ADVISE FURTHER REGARDING EXPEDITION AT STEVE'S FORMER SALARY TO YOU STOP NEW RADIO FOR CALLISTO ON WAY STOP YOU SHOULD KNOW NOW HOW TO SETTLE CONTROVERSIES THERE IF ANY STOP HAPPY LINCOLN'S BIRTHDAY

JOHN HARGROVE FOR ASSOCIATION.



THE CARBON EATER

by DOUGLAS DREW

THE CARBON EATER

By Douglas Drew

The Martians, being silica-based beings, had a simple way of ruining Earthmen: just turn loose a carbon-destroyer!

"LISTEN, Buck, if you don't like the way I conduct my life, why don't you concentrate on someone who suits you better?"

There was an edge in her voice that made me squirm, but I couldn't do what she said any more than could those other four saps. We were just like trained seals under her whiplash. Only it was worst of all for me, because I'd been her trained seal ever since we were kids together.

"Listen, yourself, Holly Webster! I'm not trying to order your life for you, though some man ought to. But I *am* yelping because you've given me a dirty deal!"

A neat, practical little hand rose to soothe her throat, which softly palpitated in mock fright. Blue eyes gazed in round wonderment. "Who, me? What do you mean, Bucky?"

When she said that I got mad. "You never gave anybody a fair break in your life. I don't know why I ever helped you get into our outfit. You've kept five of us miserable ever since."

"And since that time you've all done better work," she came back, cool as ice. "Besides, I would have joined this outfit eventually whether you helped me or not."

"They didn't want a woman on the First Field Chemical Corps."

"An antiquated prejudice. Still I'd have made it."

"Yeah, by your looks—sex appeal."

Her lovely shoulders lifted in an almost imperceptible shrug. "About that dirty deal—"

"That's what I'm going to talk about," I snapped. "I've always wanted to get sent on a far field job like this Mars business. All my life I've wanted a chance like it—a chance to get somewhere—to see something farther away than just Great Lakes or Louisville. This was the thing I've wanted. But you had to gum it for me. You've been in command of our outfit over a year. I've taken a lot with no back talk, but this last trick is the lousiest, the rottenest, the—"

"Feeling sorry for yourself, aren't you, Buck? Cool off. I'll tell you all about it."

I growled: "It'll take some telling."

She was mighty sure of herself, as always.

"In the first place," she said archly, "members of the First Field Chemical Corps are supposed to devote their minds to work assigned them—not to anticipation of joy-riding the Solar System."

That was an unnecessary crack, but I let her go on. After all, she was my superior officer.

"According to orders we must leave Earth by noon tomorrow. I have already seen the ship provided for us. It carries a maximum of eighteen passengers. There are twenty members in our unit. Obviously, two must remain here."

"So you named me and Luke—little Luke who worships the ground you walk on."

"Luke is a photographer, a very good one. Nevertheless, the least needed member on this job."

"And me? I suppose I rate second in uselessness?"

"Very likely, but that isn't why I specified your staying here." She smiled irritatingly.

I ground my teeth. "Then it was just spite, after all, wasn't it? Just spite because you could never make me one of your little 'yes' men."

"Get this, Buck," she says, dropping the smile act. "Whether you like my way of doing things or whether you don't, remember that I serve the Empire and whatever I choose to do is toward that end. Spite doesn't enter into it—nor favoritism."

Mad as I was, I knew there was truth in what she said, for the very word "Empire" had always made her get starry-eyed, even as a kid.

"You're an idealist, Buck—impractical. You don't like it because I use my brains to get what I want. You wouldn't use pull to get anything, would you, Buck?"

"I would not!" I declared stoutly.

She nodded. "That's why I didn't put you on the list for Mars."

She was like a cat playing with a mouse. You could see she enjoyed it. But I was still in a fog. "I don't get it."

"Well, I'm not keen on that ship they've got picked for us, and I happen to know that another one, the *Sun Dolphin*, is fueled and ready for travel. She'd make Mars five days sooner and is better equipped for emergencies."

"Well, why don't you get her, then?"

"Naturally, I tried. I just don't know the right people and the ones I did contact weren't susceptible. But *you've* got some close friends over at Rocket Center, Buck. You've got *pull*. And bearing in mind how you feel about the trip, I might add that the *Sun Dolphin* can carry twenty passengers."

I GOT OUT of there fast before calling her any of the things that kept popping into my mind, and smoked half a dozen cigarettes end on end, damning her to eternity and swearing I was through.

Then I phoned Rocket Center and talked to Marty Ross—told him the whole story. Marty said he didn't like her either. He'd interviewed her that afternoon and refused her.

"She's victimizing you, Buck, like she does everybody. But don't worry, we'll get you in on this trip to Mars. Your outfit can ride the *Sun Dolphin*. Though, honest, I hate to let that dame have her way."

When I'd had a chance to think it over I realized my luck. After all, I could only hope to be a sort of general handy man on this trip. Each of us twenty was a specialist. My own flair was chemoplastics. But the rest of the corps ran the full range from chrystolography to chemotropism. So I was lucky to be included at all.

Early in the morning we received orders to get off without delay. It was still a dim half light when we reached the ship. Then, while we were getting our stuff aboard, some special news came through and radios and audiphones began issuing the latest word from Mars.

That was when we got our first lowdown on what was really happening there, and I think everyone of us felt a chill of apprehension. We didn't compare opinions. We didn't talk at all. For until now we had only known that certain of our Martian mining colonies complained of peculiar atmospheric conditions which we were to investigate. But now one such colony broadcast, in terrified phrases, that it was under poison gas.

A speaker was being put on the air—a recently arrived colonial officer who would attempt to clarify the situation, he said, by means of certain government intelligence withheld until now. For instance: On Mars, over a week ago, some prospectors turned up at Red City with a rumor that mass migration of native Martians was taking place toward the chalk deserts far to westward. Similar movements were authenticated later by a low-flying Empire patrol. When special planes were sent out to check these migrations, the moving columns had vanished, and shifting dunes had obliterated all tracks.

For the past week the Empire Intelligence Department on Mars had sent out planes to search the planet for some clue to the mystery. But they were handicapped

by observance of that long-standing law which forbade either Martians or Earthmen to trespass or land any ship upon the other's territory.

During extreme darkness of the fourth night every trade city on the border was evacuated by its native inhabitants. Only two Martians were found. These were secretly held for questioning by Colonial Intelligence. But at the first opportunity, both committed suicide.

Anxiety was everywhere. High officials grew tense. The Empire Council on Earth was demanding some explanation. Meanwhile, there were subtle atmospheric changes—chemical by nature—which began to affect workers of our eastern mines. They were robbed of normal energy. Their skins were attacked by growing sores and their muscles softened.

Colonial chemists were unable to cope with the phenomenon, so the Empire's First Field Chemical Corps had been called. The gas, for at last it was recognized as such, had slaughtered six hundred inhabitants of one Deep Valley settlement, and those remaining in the valley now were existing solely by protection of gas masks and fabricated oxygen supply within their mines. Outlying districts to the south also reported atmospheric change and noticed, too, the same lethargy on the part of outdoor workers.

An expedition of planes was sent to the town whose inhabitants had been wiped out. They landed and by radio verified the rumor of holocaust. They wore gas masks and air-tight clothing and went looking for survivors. Some took samples of the gas. It was colorless and odorless.

Some suffered pain and retreated toward their ships. Most of the rest followed in alarm. Less than a dozen ever reached the cabins of their planes. Only two planes ever left the ground. Both crashed. A dying pilot radioed his base near Red City. He said their gas masks had failed, also the air-tight suits, for the poison penetrated both.

THE GOVERNMENT at first withheld this information, pending evidence which would indicate a state of war. Conclusive proof now existed that the gas menace was the forerunner of a war of extermination which Martians intended to wage against men of Earth.

The speaker closed with ringing words: "Men of Earth, rally to your Empire! Our colonies on Mars are desperate! Without those mines we cannot stand against this enemy. We must defend our rights and preserve the right of humankind to live."

Then the radio was silent, with only sputtering static to break our awed silence. Someone whistled and uttered a low rumble of profanity. I looked up. It was Bull Balfour. Bull didn't even realize he'd spoken. I saw Holly Webster, too. Her face was partly paled and partly flushed.

Barney Oberteuffer for once in his life couldn't think of anything funny to say. He sat with his face blank, staring at Holly. So did old Thompson and little Luke. Only Thompson's usual philosophy didn't seem to be getting anywhere right at that moment and little Luke was, if possible, sadder than ever.

Probably I should be ashamed to admit that my principal annoyance with the whole thing was that now I wouldn't have a chance to get anywhere with Holly. I'd been nursing the optimistic belief that, once we were on our way, she'd be idle and I'd have a chance to get her off by myself.

But I couldn't get her alone, for she stayed by the big radio, constantly afraid of missing something. And whenever I butted in she made it clear that I was the least important thing in her life. The Empire demanded her, she said; it demanded all of us. Frankly I couldn't see why that need make her so infernally standoffish.

There's no use arguing with a girl, especially like Holly. So I wandered about the ship, hugging my self-pity and pretty soon, as was natural, found myself in company of the other four devoted ones—Bull, Barney Oberteuffer, Thompson and little Luke.

"You're a bunch of trained seals," I told them. "Suckers, every one of you. Each of you thinks he's got a chance. Well, you haven't. She doesn't know you're alive. She's busy worshiping an abstract ideology that she calls 'Empire.' She's no woman. She only looks like one."

They stared at me sort of pityingly.

All except little Luke. He just looked sad like always. Bull raised his great head, shook a mane of blond hair and blinked, making sure of my presence. "Scram," he said hospitably. "We didn't ask you anything."

Cheerlessly ignoring him I sat down and punctured the ensuing quiet with a couple of questions. "Any of you birds ever see a Martian? What was he like?"

Lou Thompson had seen Martians, had known two or three personally. He'd never been to Mars, but he was older than the rest of us and remembered back before that law was enacted, forbidding Earthmen and Martians to trespass on each other's land.

"They were peculiar folk, smart as anybody, but seemed irresponsible. Never could trust one. They kept our jails crowded.

"They were killers, too. We executed some and it made bad relations with their government. So that law was made just to keep things smooth for trading. You know, we paid cash for every square mile of our colonies on Mars. We let them set the price, too."

"Well, where are they now?" I interrupted. "According to reports they've vanished—all of them!"

No one answered me. I guess no one could. It was a foolish question. After a time old Thompson said: "You know their evolution, of course."

Of course we all knew, but no one stopped him, so he went on: "A gentle race of masters, men of genius, overthrown, almost entirely destroyed by brute slaves, then an interbreeding. Result—a race of creatures with neither conscience nor code, treacherous beyond belief, yet strangely retaining now and then a flare of scientific genius."

WAR! We'd never had a war during my lifetime. Still, I'd read about plenty of wars in the past, and for the life of me I couldn't see how we were going to fight a war with none of the enemy in sight. My private belief was that they had suddenly taken fright at some imaginary danger from us, built an oversize fleet of spacecraft, and retired to Venus, dropping a few gas bombs to cover their retreat. It was natural enough for them to go there.

Venus had belonged to them for centuries and, although Earthmen considered it a hell's caldron, still the Martians, with their silicon body tissue, found it not only tolerable but to their liking, and for generations there had been more Martians living on Venus than on their own home planet.

I tried this line of reasoning on the boys. They didn't think it sounded foolish and we were all cheered up. Pretty soon the gas would dissipate into the atmosphere and Earthmen could go ahead into the old Martian territory and fortify it against their ever returning. They could call *that* war if they wanted to. Personally, I called it a cinch.

By this time we had passed beyond radio communication with Earth and, no more news being available, I don't think most of us even troubled our minds about war or poison gas.

My own impulses once again followed their natural pursuit—Holly Webster. I found her deep in a book. "Feeling disappointed?" I asked.

She gave me a cold impersonal.

I explained: "Thought you'd be feeling bad not to have a chance to pour glamour on male Martians—not any male Martians left." I sighed. "Tough."

"What can you remember about Martians, Buck—from the stuff we had in school?"

"Not much," I grinned. "They look like us except they're glassy. But really they're different. And they eat sand and stuff."

"Martians convert silicon," she recited. "Is that all you can remember?"

"That's a lot."

Holly actually favored me with a smile. "I can see you were teacher's star pupil."

"Teacher had blue eyes like you. She was swell."

"Buck, your scientific qualities blossomed early."

"I am descended from a long line of traveling salesmen."

"I was certain of it. But you have horse sense. Everyone in our outfit has genius except you. And they all keep their minds on the job assigned them."

"You're forgetting four," I told her. "There's Bull and Barney and old Thomp-

son and little Luke. They gaze at the Moon, too."

She shrugged. "Jealous?"

"Not me," I lied. "Got too much horse sense."

Our optimistic interlude was brought to a close when we entered Mar's outlying zone of radio communication. The poison gases were *not* dissipating into the atmosphere! In Deep Valley every man, woman and child was dead. Valleys to the north had been decimated and the lethal area expanded daily.

The colonial capital, Red City, only four hundred miles beyond the poison zone, was already packed with more refugees than it could feed or shelter. Colonial chemists had failed utterly to analyze the gas or to locate the source from which it sprang.

No more Martians had been discovered for questioning. The governor had sent two spacecraft to Venus to seek help or information from the Martians there. The two ships had remained aloft in compliance with law and, establishing communication by radio, had described the chaos upon Mars, and asked assistance and advice from Martian scientists on Venus.

Presently a voice answered them. It said: "Earthmen, your message pleases us. It is just the beginning. Soon no more of your kind shall be alive on Mars. Then, after a brief period, your spacecraft will cease to fly, for you will have neithers duels to burn nor metals for building. After that we shall come to Earth in great fleets, destroy your few defending ships and do as we will with the green planet. Perhaps by Martian tolerance some selected tribes of your people will be permitted to live—within restricted territories of the Martian Empire."

Then over the audiphone came soft laughter and in an aside a low-spoken command. Immediately there was a searing flare of light and a shaft of pale yellow-green leaped toward the spacecraft. Both ships darted aside and blasted upward and away, but the terrible yellow-green ray continued to wink and swing, boring after them far into the deeps of space, as they zigzagged to escape. One ship turned incandescent and fell, a molten cinder. The other reached Red City and delivered the Martian's frightful prophecy.

Colonists awaited the coming of the First Field Chemical Corps with such trusting faith that we were sickened with fear of our inadequacy. Nobody said much. We just sat around the audiphone listening. Holly's face was terrible. I guess her imagination carried her further than the rest of us.

The Red City rocket field was ready to berth us, when we received a special message from the governor. He believed the source of the gas was located. A small rocket had just crashed beside the crater of an extinct volcano in the Three Range Mountains. There was a tiny lake there. The pilot had died while sending the message, but he'd given his exact position.

The governor sent that position on to us with the suggestion that we go directly there and do as we saw fit. He added that, in case we anticipated using oxygen tank space-suits outside of our ship, the standard equipment would not resist the poison's corrosive action longer than twenty minutes and the ordinary type of gas mask was not to be trusted at all.

Command of our ship was now automatically turned over to Holly Webster. I guess I already said she showed strain. I watched her as she spoke a few words into the transmitter, trying to sound confident. She was positively gray. It was a good thing we hadn't a viso-screen. If the governor had got one look at her face, he'd have given up right then.

We dropped slowly under perfect control. Little Luke and I watched Holly. She was studying the lay of things below with a pair of binoculars. The crater lake was close, only about a hundred or so yards beneath us. Big bubbles continuously broke the surface.

Holly beckoned the pilot. "Can you hold us right here a few minutes? Good! Then, quick, drop a line down and get a sample of gas. And drop a cage of rats, too."

Five minutes later we had our samples and went helling away from there. Holly was a little flushed and I thought she seemed to be more herself, as if she'd scored the first hit.

I didn't get it. "Why the hasty retreat?" I asked.

"You know what fierite is?"

"Sure," I said. "This hull is made of fierite. All rocket craft are hulled with fierite. It's noncorrosive."

"That's what you thought," she came back. "I just spotted the little rocket that crashed down there. It was pitted all over and eaten clear through in some places."

WE LANDED on a stretch of desert, well outside of the death area and went straight to work on the samples. It hadn't bothered the glass tubing at all. That checked with the report sent us by the colonial chemical outfit. But that was about all they *had* found out.

"Well, it's something, anyway," said Holly. "Now, Buck, you're a plastics man. They say a standard spacesuit resists gas penetration for twenty minutes. What are those suits doped with?"

"Kroner's Super N," I answered.

"I guess that's Greek to me," she shrugged. "What's in it?"

"Converted rock fibers, mineral oils and cotton gum—complex as hell. Formula a block long."

"Can you get it—or make it?"

"Sure."

"Good. Then call Red City and order the ingredients and plenty of fine mica scale to go in it—as much as the dope will carry. And order a couple of fast paint-spray outfits for exterior hull work and a lot of oxygen tank spacesuits. We'll re-dope them every fifteen minutes if necessary. Tell them to hurry."

My stuff arrived and in less than an hour I had tanks of Super N stowed aboard the *Sun Dolphin*. The paint-spray outfits were fast bôys, all right. They tuned up their apparatus and in no time our ship was completely coated and drying.

We told Holly. She just stuck her chin out of the laboratory long enough to tell the engineer to get going. Then we were off.

On our way we doped a bunch of spacesuits with an extra coat apiece. I grabbed one as soon as it was dry enough not to be sticky and got into it. Holly climbed into the next one. She looked funny in it. I spoke to her by the radio headset.

"You've lost your superiority," I told her. "You bulge in all the wrong places."

She didn't even favor me with a call-down, but presently I saw her backing up to a mirror and surreptitiously trying to look over her shoulder—impossible in a spacesuit—and I was tickled, for it proved she was at least *part* girl. We were the only ones wearing the things right then, so no one else could hear me.

THERE WAS scarcely a jar as we made our landing, right by the brink of the little crater. Holly and I were the first ones out of the lock. The bubbles were big and they broke the surface at a great rate. My guess was that that caldron heaved out a couple of hundred cubic feet of gas per minute. Subsequent and more accurate estimates figured over twice that amount.

The bubbles poured up without variation in just four places. These places were patterned evenly across the surface, the nearest one not over nine feet from the parapet on which I stood. I thought it would be a good idea to get a sample of those breaking bubbles fresh from their source, so I ducked back into the ship and found a bamboo rod just long enough. I wired a glass trap tube on the end and hurried out again.

A lot of others had donned their suits by now and were standing around trying to get an eyeful. They got it all right. When I reached out to get my sample, the end of that pole just started to wither right before my eyes. It turned whitish and drooped while it was still a foot above the breaking gas. Then the whole end, trap tube and all, fell away. It gave me shivers.

I looked up and saw Holly staring at me, nodding. It was now a certainty that here was the source of poison gas. Jets! Poison-gas jets. Four of them down there. I wondered how far down they were, whether we'd be able to reach them, or just what we should do.

The water was translucent, but not perfectly clear. We'd have to put some divers and cameras down to see just what was what. I splashed my bamboo pole in the water's edge. Did you ever poke a straw into a candle flame? Well, that's just what happened to the bamboo, except that there was no smoke—only a soggy white ash that sloughed off.

"Hey!" I yelled into my headset. "Get back! Be careful of this stuff! It's already impregnated. It's absorbed the poison!"

Holly's voice came to me, cool, self-assured: "Keep your shirt on, Bucky. It's no phenomenon. Didn't you ever hear that water absorbs gases?"

Of course I know that. Every schoolboy knows that. But for the moment I was shocked and horrified because this new circumstance was one which might baffle all our efforts, as, indeed, the Martians must have intended it to do, planning in advance to keep those jets beyond the reach of divers.

I can't even begin to describe all the different jobs that Holly directed. She gave Bull Balfour two husky helpers and put him to work taking soundings and making an underwater survey. Barney Oberteuffer, using a long steel rod with a scraping gadget and a trap on the end, took samples of the lake bottom at different depths and different positions down around the jets. Another fellow took samples of the water itself at varying depths.

CHEMISTS worked in the laboratory unceasingly, trying to break down the samples and find out what made them tick. Another laboratory group was trying to find some neutralizing agent to counteract the poison. But it was neither alkali nor acid and what seemed at first to suggest a radioactivity, later contradicted its own analysis.

To facilitate an underwater survey the engineers had swung four cable-walks across the lake. Little Luke crawled out on one. He was scared stiff but he had his orders and started lowering lights down there on doped cables and a big camera all cased up in glass. Looking out a port of the *Sun Dolphin*, I could see his hand tremble as he timed the exposures. I hoped Holly wouldn't notice and kid him.

She had put me to work again on plastics for sealing up buildings in Red City against the time when poison should get that far. Naturally I tried the old standbys—potassium and sodium silicates. In theory they would work. In fact, if I could have made them stick, they would have worked in actual practice. But the stuff wouldn't stick—not to stone or wood nor to anything when that gas started chewing under it. It pulled at the edges or at any little pinhole and then came off like a sunburned skin.

Tile and brick withstood the corrosion, but mortar crumbled away. That was a tough break for a starter because most homes were built of those two materials. Holly kept two wave lengths busy on the air. One radio brought in communication of all kinds. The other carried nothing but reports from constantly patrolling planes that checked every shift or expansion of the danger area. A man was constantly at duty by this radio, recording each item upon a wall map.

At sunset the word was passed around that Holly wanted us to knock off work and have supper together if possible—that is, just our outfit, the First Field Chemical Corps.

We all managed it, leaving assistants to carry on. She called a man of each job to tell us how his group was doing.

Old Thompson, first, admitted that, in analyzing the poison, they had got exactly nowhere. The other laboratory group, the one trying to produce a neutralizer, had suffered the same experience. Then Bull told us his luck with the underwater survey. It didn't simplify matters much. The sounding line had indicated a great confusion of gnarled and protruding rocks below the surface. Probing with rods had confirmed this but had established the greatest depths as roughly thirty-five feet. He thought it was a fair guess that the jets were somewhere at that level.

Holly said she hoped we wouldn't have to proceed purely on the strength of guesses. I felt sorry for the big guy. He was the man of action of our outfit, but tonight he just rolled his eyes at Holly like he was a whipped dog. Bull never went in for alibis. Later, of course, we realized that those rock protrusions down there were *fixed* just to prevent such a survey.

I THOUGHT of little Luke and his underwater camera work, and noticed that he wasn't with us. Some of the others must have had the same thought, for his absence was commented upon.

Holly said: "He's sick. He's in his bunk." Her tone didn't denote any more sympathy than an icicle.

I asked her: "How did he make out?"

"He didn't," she replied, "I wanted him to get a shot of each jet, but he couldn't get a register of anything below fifteen feet."

She turned to me. "How far have you got?"

"I haven't," I told her, and grinned foolishly to cover my embarrassment.

"Not amusing." Her hard little mouth cracked the syllables.

Next was a handful of engineers. They had investigated a notion of draining the lake down to the jet level. This was Holly's own idea and I think their report upset her more than anything the rest of us had said. The engineers had checked the possibilities of each phrase.

The lake could not be pumped out, for no pumping apparatus could withstand such fast corrosion. Although it could be siphoned, such an operation called for more than a mile of glass pipe line to reach the necessary levels and the fabrication of such a line would mean weeks of delay. A channel could be blasted from the kale but it would have to be cut through solid quartz. Long before such a program was complete, our colonial population would be wiped out.

"Look," she said, "I want all of you to see this map." She pointed to the one on the wall. "Here is the present extent of the poison zone. Mountain ridges are holding it in check here—and here. So long as prevailing winds continue or, should there be no wind, the gas is not likely to approach Red City faster than one to two miles per day. Of course, if a southerly wind should blow, this part—she pointed to a huge gassed area that spilled from the lower end of Deep Valley—would move into our most heavily populated districts and cover not only Red City but Port John and New Thames and towns west of there."

She paused and I asked: "What'd the local weather bureau have to say?"

"Continued westerly for at least a week. Perhaps then—but they understood the situation. If a southerly wind springs up, all inhabitants will be warned at once."

An ironic silence followed that remark, for we all saw how much good warning would be. It was just like telling a condemned prisoner: "Look out for the electric chair. It's going to burn you."

Nobody had anything to say for a few minutes. Then Holly muttered: "The rats died because all the carbon was eaten out of them. Carbon is the diet of that stuff. If there were any normal earth-like carbon vegetation on this planet, such a poison would be absorbed.

"You laboratory men, keep your heads clear. Keep your work thorough. According to the weather bureau, you've got time to lick this thing. We're going to bomb the bottom of that lake tomorrow and maybe damage whatever apparatus is there."

I didn't think the bomb idea was much good because the Martians were too clever to leave their gas-producing apparatus in a vulnerable position. Especially when they had a whole mountain of quartz in which to hide it and plenty of time to pipe their gas through to the jets.

SURE ENOUGH, the bombing episode was a flop. Not only did it fail to affect the four torrents of gas bubbles but it cluttered up the lake with rock fragments in such a way as to make Bull's underwater survey even more difficult.

All morning I was busy with an architect from Red City. There were about a dozen huge hotels and office buildings built of brick and tile. As shelters, their principal weakness was, of course, the mortar used. I phoned them the formula of an ancient Twentieth Century potter's glaze. They mixed this paste in great quantities.

Scaffolding was rigged nine stories high against the walls and the stuff was painted into every mortared seam. As fast as it dried each painter was followed by another man who fused it with a torch. These buildings, when finished, would be safe, for the poison would never reach their higher stories.

The moral effect was tremendous. Every man began to look for ways and means to fortify his own home, which was a good healthy reaction.

For the next two days I couldn't get my thoughts away from that map. The poison zone had expanded into a gigantic area, covering so many thousands of square miles that you could hardly believe it all came from our little crater lake. But the Colonial Chemical's scouts had proven there was no other source. It just showed

how much the infernal stuff expanded when it got loose. At such a rate, the habitable parts of the whole globe might soon be covered.

Holly had an eye on the map, too. It had her worried. "Listen, Buck," she said. "I want to go over that Super N dope formula. We've got to carry it a little further somehow."

"What's the matter with it the way it is?" I asked her. "Seems to be doing O. K. with that admixture of mica scale."

"It won't stand the lake water."

"Neither will ice stand a bonfire," I retorted. "But what of it? Don't tell me you'd like to send a diver in there."

She half lifted her arms in a little futile sort of gesture. "Somebody ought to go down and find those jets."

"Don't look at me," I said. "I'm not that dumb, nor that heroic. Besides, no man would live three minutes in there—not if he wore a suit of Super N an inch thick."

"The army has got some incendiary bombs that'll work underwater," said Holly, talking sort of to herself. "They'll burn underwater. They're so hot they'll melt granite for two or three feet in all directions. They'll fuse it. They'd melt those jets and seal them up tight."

"That being the case," I suggested, "why not just drop a bunch down around the bubbles?"

"That's what the governor thought," she said, "but it won't work, because the heat expansion will cave in a lot more of those rock grotto formations and afterward we will never be able to reach the jets again. So we've got to be sure the first time to seal up every jet. At least, that's what Mr. Balfour advises."

"If Bull Balfour says that, then it's so," I told her.

"Then we'll have to do better with the Super N," she argued, looking more and more like a scared kid.

"Kinda grabbing at straws, aren't you?" I asked.

But right away she was all business again—soldier of the Empire. "We'll go over the formula at once. It must be developed. It can be, I am certain."

We went over the formula, the whole business of it, a dozen times. When we got through she knew as much about Super N as I did, which wasn't nearly enough.

"All right," she told me, very decisive. "I'll take over from here on. You go to Red City and help them with their defense measures."

A SMALL ROCKET of the Colonial Chemical outfit came for me and an hour later I was in Red City. The chemical boys had been pretty active in the defense work and escorted me all over the place. Such mines as could be utilized were being sealed up with brick and glazed mortar, and stored with food and oxygen equipment. Everything moved smoothly and fast, but still the job would take weeks.

Factories were turning out spacesuits, doping them as we had requested, by tens of thousands. High officials of Earth Empire cursed us and prayed to us. They were frantic. They had sent another ship to Venus, established communications there with the Martian government, had argued, pleaded and threatened, and had been laughed at and shot at for their trouble.

I was allowed to interview the governor, a pompous old-school politican, and scared to death. I wasted no time, but studied a map of the principal cities, then went out in a plane with one of the local boys as guide, and flew over and got an eyeful of each town. The whole situation looked ordinary. Of course, if the weather held long enough without change, things might work out all right. That is, providing we meanwhile found a way to stop the flow of gas.

I asked my guide why Red City and these other big towns weren't being evacuated. He said the governor was afraid of starting a panic. Personally, I thought that was a hell of an answer.

It was late afternoon when I got back to Red City and had an immediate audience with the governor, determined to organize some means of moving the populations to a place of safety.

Perhaps I sounded too anxious. Anyway, the governor wasted five minutes airing his perfect composure and assuring me that there was no cause for alarm.

I remarked upon the quick change in his own state of mind since earlier in the day. "Since then," he said loftily, "there have been two vital developments."

I damned him under my breath. He

was like a ripe old gossip with something juicy. "Well?"

He smiled. "At two o'clock I received a confidential report from the weather bureau stating that a southerly wind must be expected before morning."

My blood froze. I felt a chill start at my spine and gnaw inward. I stammered something, but he went on.

"Naturally, I did not release this news. The outcome would have been frightful—mob fear—stampede—panic. Instead I sent a private call to your commanding officer, Miss Webster, informing her of the situation. I must admit to suffering much anxiety at the time and during the minutes that followed. But presently she called me by radio. What she told me described the second vital development of today.

"The situation could be mastered at once, she assured me. The flow of poison gas should be stopped within a few hours. Four divers are going down in the lake to plant incendiary bombs beside each jet. These bombs, at terrific heat, will melt and congeal the rocks, collapsing and permanently closing whatever form of outlets are there. Today, she herself overcame the last obstacle to this plan by perfecting a suitable compound with which to coat the diving suits."

I was struck dumb. How the devil had she managed it? This news was so big that at first I couldn't realize its immensity. Then I began thinking I'd better get out there fast. Of course, I never said Holly wasn't a whole lot smarter than myself, but those protective dopes were old stuff to me. I might be useful.

"A rocket is going out presently," the governor said, "taking an expert on the new incendiary bombs to give last-minute instructions. I suppose you can go along, although I'm sure you'll find your superior officer has the matter well in hand." He was awful cocksure.

NOBODY was outside the *Sun Dolphin;* that is, none of our outfit. Curiosity had drawn a few visitors but they were just waddling around in doped suits at a safe distance from the lake, getting a big thrill out of being scared. So the technician and I went on into the ship. It was like a tomb. Even the radio and audiphone racket was cut down to a whisper. I heard Holly's voice. It had a queer note.

They were all gathered in the mess room, sort of sullen and quiet. Only one other person besides Holly was standing. That was old Thompson. He looked very straight and soldierly in spite of his skinny neck and baggy, acid-stained jacket.

Holly's chin was up and her eyes traveled levelly from face to face. I loosened my helmet plates so as to listen in, and heard her say: "Well?"

Bull Balfour wore a glowering frown. Suddenly his features relaxed. He said, "Nuts," and got up and lumbered over to stand beside Thompson.

"We need two more," Holly said.

Then I knew what it was all about. She was getting her four volunteers who would go down and plant bombs. And they didn't want to go. They were scared stiff. I didn't blame them. We'd all seen enough to feel that way. I personally remembered how that bamboo of mine had whitened and sloughed away. We'd all of us seen too much.

Holly was looking at me now, glamour oozing out of every pore. "Hell," I told myself. "Empire or no Empire, I don't wanna an' I just ain't gonna." I rolled my eyes ceilingward, puckered up my lips and started to whistle, very soft and nonchalant.

But she didn't waste any time on me and I think it was right then that I commenced to get suspicious, although I couldn't exactly put my finger on what was wrong.

The rest of the gang just sat there looking sheepish. All except Barney Oberteuffer. He couldn't actually clown about it, of course, but he did squirm and smirk a little, pretending that his refusal had some element of humor about it. It was a pretty thin piece of play acting, even though he tried harder than he ever had in his life.

Holly stood watching him. She was sure a swell-looking girl when she wanted to be. But her lip curled some, sort of piteous and disgusted and a little bit ashamed. Then Barney commenced to get red. He must have known she saw through his play acting. He never said a word, just got up kind of tiredlike and

went over to join Thompson and Bull Balfour.

After that you could pretty near feel the gang's antagonism. Their eyes didn't flicker and their faces were like so many blocks of granite. They didn't like her method. She sensed it, too.

"One more," she said, very calm, but not fooling anybody. It was plain as day that she wasn't sure of getting her fourth man.

I glanced at Bull, towering there beside Thompson and Barney Oberteuffer. "Trained seals," I thought. Well, I was one seal that wouldn't do tricks this time. I wouldn't be in those boys' shoes for any female. It gave me creeps just to think of that bubbling hell.

THERE was one other of Holly's trained seals that didn't intend to go, either—little Luke. He was such a picture of misery that I almost laughed. She passed him by. I couldn't blame her. He didn't look like much of a specimen of manhood. He rolled his eyes at the three who had volunteered. They were his buddies. You could see shame written all over him. Then I caught his eye and winked to make him feel better. He jumped and cringed as if I'd hit him.

Holly was now turning it on our chief metallurgist. He was a smoothy, hadn't been with us long, but we'd already found out he had a flair for racing planes and other men's girl friends. Guess she figured a gambler like that would take a chance. She smiled kind of tantalizing. He smiled right back, very friendly.

"O. K.," she said. "Come on, then. Stand up."

"Nice weather we're having," says the metallurgist.

She got red. Some of the fellows laughed. Most of the others relaxed a little and grinned. Holly was baffled and showed it. I was all set to snub her again and wondered why she didn't make another pass at me. After all, she'd had me pretty well disciplined ever since we were kids. But she glanced right by me as if I weren't there.

I figured Holly was all wrong—this shouldn't be a volunteer job, anyway. The best-fitted men should have been ordered to do it, or else they should have been chosen by lot. Then there wouldn't have been any feelings involved. I knew Holly was smart enough to know this and that made me still more suspicious.

"Only one more." She was being cheerful now, voice-with-a-smile stuff. Nobody tumbled. For a full minute there wasn't a word spoken. One after another they met her eyes, too, but they weren't falling for it.

I never saw Holly look so swell. I remember thinking we ought to have such scenes oftener. Honest, she was beautiful. If she'd eyed me just then, she'd have won. But she didn't, and a second later I got hold of my common sense. However, she was still beautiful and it set you on fire just to look at her. She certainly had what it takes to bring a man to his knees. But these guys were hard.

Just for one fleeting moment I thought she seemed panicky. I figured she was licked and started being sorry for her and wondering what we'd better do. Then she turned it on little Luke.

It was horrible. He was crazy in love with her, anyway, and I know she'd never looked at him like that before. Besides, he'd been scared to death ever since we got to Mars. And now he turned white as chalk. He didn't move, didn't shake his head or nod it. His eyes, big, dark, round saucers, were like those of some stricken animal.

"Luke," she said, looking real helpless and in need. "Luke, you're not yellow."

I don't think the poor little squirt could have answered her if he'd wanted to. She walked slowly toward him. "Don't you see, we've *got* to have one more man." Her voice was plaintive, yet somehow she managed to put a subtle emphasis on "man."

She bent over him. Luke gulped and glanced up, met her eyes, and looked away real quick and gulped again. I could see his Adam's apple bulge and jerk. He mumbled something vague and negative. I thought he was going to be sick. But Holly straightened up with a sigh and an expression of wonderful relief. "You will, then, won't you?" It was a statement, not a question. We all knew damn well he hadn't said any such thing, but Luke was staring at her now and she looked so unearthly happy and saved that he just nodded. He shuddered when he did it.

Holly swept up the aisle looking pleased

as Punch and ducked into an adjoining telephone compartment. I was burned up and wanted to say things, so I followed and got a shock. She was crouched in there sobbing like her heart would break. Things like that embarrass me, so I sneaked out again.

But I didn't want to face any of my outfit right away. It seemed as if we'd all gone through an analysis. Some had come out fools; the rest of us, something worse. We all looked pretty contemptible, Holly included. So I went into the corridor that led back through the tail sections and into the last compartment, which had been rigged up for little Luke's photographic apparatus, figuring to grab a smoke and try to recover some of my alleged common sense, and get a more reasonable attitude toward things.

I WISHED I knew what sort of dope Holly had evolved to use on those diving suits. I couldn't figure it out. Only there was one thing you could bank on every time; when Holly Webster set out to do something, she *always* did it.

Somebody came in right after me. It was little Luke with a pile of stuff over his shoulder so heavy it made him bend. He set it down and locked the door. Then he saw me.

I grinned. I didn't want to, but just couldn't think of any other way to face him. He reddened some. "Skip it," he said, "I know how you hate heroics."

That made things easier, "Squirt," I assured him, "there's nothing heroic about you. Why the hell did you do it?"

"Same reason the others did, I guess. We're just trained seals, like you say."

"What are you doing here," I asked, "trying to duck out?"

"They're getting instruction on the incendiary. I don't need it. I know how the things work. I just wanted to get into this stuff here—get the feel of it." He bent over the pile on the floor and now I recognized what he'd been carrying. It was one of the doped diving suits.

I jumped to examine it. No wonder the little guy had labored under its weight. The helmet itself must have weighed twenty-five pounds. Each thick, lead-soled shoe weighed at least that much and the whole body fabric was coated half an inch or more with rubbery dope, very much like the stuff I'd been making.

"What's it made of?" I asked, fingering it.

"Dunno, but Holly says it'll do the job. And if she says so, then it will."

"It looks and feels like Super N," I told him. "And, furthermore, it smells like Super N."

"Which is all Greek to me," says Luke. "I'm only a photographer."

I felt too rotten to talk and just watched while he got into the cumbersome suit and shortened straps and what not until it was more or less cut down to his half-pint stature. He looked ridiculous, and pathetic, too, and all set to be a hero.

His room, being the last tail compartment, had an emergency port through the outside hull. It was tight closed, but not locked. Luke pushed it open and waddled through and down toward the lake's edge. I sealed up my helmet plates once more and went out, too.

THERE WAS a low parapet of feldspar rock right at the brink. Luke stood looking at the depths before him and squared his puny shoulders. I could picture his mood inside that massive helmet, telling himself there was nothing to be scared of, that if he did as Holly ordered, everything would turn out O.K., like it always had in the past.

After a minute he started to come up toward the ship but stopped short like he'd forgotten something and went back to the pool. He hoisted one leg over the parapet. I got nervous and ran down to stop the little screwball from doing something crazy.

But he seemed to know what he was about. He motioned me aside and I saw what he was doing—dangling his foot above the water so that the bottoms of the thick, lead sole just touched the surface. Then he heaved it back up on the ledge, squirmed around until it was sole up, and bent to examine how the dope reacted to the water. The stuff was oily and the water ran off. He raised his head to look at me. I couldn't see his face, but I knew he was grinning. He made a sort of "I told you so" gesture with one hand and dropped his foot down again to dunk it more thoroughly.

I saw the thick rubbery bulk of his suit

shift on the stone and his helmet canted farther out over the pool. He kicked back to restore his balance, but he wasn't used to being weighed down so. He slid a little and made a couple of futile swipes at the ledge with his gloved hands. I tried to grab him but you can't get a purchase on an outfit like that. Then he was gone, down under and out of sight.

It must have been a good thirty seconds before I saw the glitter of his helmet a foot or two below the surface, already moving toward the nearest shallows. At least the poor little monkey had kept his sense of direction.

I buzzed an emergency call into my helmet transmitter and hurried toward the place he'd be coming ashore. It took a minute to climb around some of the rock projections. By that time he was up to where the stuff only lapped about his knees. All of a sudden his strides got irregular and shifty like he winced at something. Another lurching step or two and he was out of it. I reached him just as he keeled over face down on the bare rock.

He was dead.

While I was bending over, careful not to touch him, I saw the honey-combed surface of the suit open in great eaten gaps and reveal flesh gone to a whitish pulp. I threw a quick glance around to see if my emergency call had brought anybody. It hadn't. No one, except myself, was outside the *Sun Dolphin*. Even the visitors and brass hats had gone in. Probably there was a lot of last-minute dramatics and talk, and that would be why no one had heard my emergency. For just a split second I thought I saw a face watching from a glass port. Then it was gone.

I RAN for the ship to break the news. They'd sure have to make a lot of new plans, and fast, or else this planet, Mars, would be in bad trouble. That secret of the governor's about a coming south wind wasn't going to be a joke to several million people. My mind was working like that—reasonable. But my feelings were burning hot on account of little Luke, and I cursed Holly for botching the job on that dope.

I ducked through the port and into Luke's compartment and tried the door which led to the interior of the ship before I remembered his having locked that door and pocketed the key. Now I must go around and use the forward entrance. I swung to go out again, but even as I faced about, the little emergency port clicked shut in my face. It was locked now.

Almost panicky, I tried to figure who would have done it, and why. The lock could only be operated by someone in the forward control room. Then I recalled the face I'd seen watching me from that forward port. Whoever it was had seen me hurrying to enter this tail compartment and had some reason for wishing to imprison me here.

What reason? Then it dawned on me and all my suspicions crystallized in ugly acknowledgment of fact—*I knew too much*. I must be silenced before I could tell the truth and give the game away. That dope was no good. Holly *knew* it was no good. She was deliberately sending those boys down to plant incendiaries, knowing that they hadn't even a chance to live through it. So that's why she had been bawling a while ago. I remembered again the way she'd selected her victims. I gritted my teeth and damned her brassy guts.

I tried to get a call through by my helmet transmitter, but a deep humming droned in the phones, so I knew my wave was blanketed.

Who else was in on this pretty business? A lot of civil and military officials had been hanging around Holly. A lot of pressure must have been put on her, but I knew the phony dope angle was her own idea because of that message she had sent the governor.

Whoever had been watching through that port, or whoever that watcher had reported to, must already know what had happened to little Luke and evidently, judging by my present confinement, intended to go through with the murderous program, come hell or high water.

I wondered who would take Luke's place. Someone chosen by lot, probably, for no more of the outfit would volunteer.

A PILE of prints and negatives were on the table beside me. I noticed the ones on top were curling and cracking, and realized that while the port was open the

place had filled with poison vapors. I opened a force ventilator and flushed the room, then loosened my helmet plates for a breath of air. For the first time I heard the room radio barking an announcement of what our outfit was about to do.

The speaker was addressing the colonial population of Mars, and was the type which usually describes sporting events. His voice choked with emotion. He dramatized the affair for all it was worth. The situation, he declared, was one which demanded the highest and finest of human courage. This demand had been met, he assured his listeners, by men of that valiant company of world fame, the First Field Chemical Corps, four of whose members had volunteered unhesitatingly to perform the difficult and dangerous task confronting them.

They had just been receiving technical instruction. Now they were donning specially prepared suits in readiness for a descent into the fluid of the poison lake.

He had hoped to get Miss Webster, Miss Holly Webster, commander of the corps, to speak a few words over the microphone. He was sorry, but Miss Webster seemed unavailable. She had been under a severe and exhausting strain for three days and it was being whispered that she was near the breaking point.

A few minutes ago, showing signs of terrific nervous tension, she had quietly withdrawn from active participation. However, the success of the next quarter hour would doubtless herald her once again as the great leader of a great outfit.

Through the glass port beside the mike he could now see the four divers outside the ship—no, there were only three. For a moment the radio was silent. I chewed my lips and thumbed through the stack of photographic prints beside me.

The announcer returned and barked some more. "Ladies and gentlemen, one of the four men has been declared physically unfit for the venture. However, there will be but slight delay, for, with a courage characteristic of this famous group, another has already volunteered. He will presently join them.

"An atmosphere of feverish anticipation hangs over all spectators. I cannot describe the feeling which affects all who watch the churning surface above these poison jets—the rise and darkening swirls of deadly vapor—"

I switched him off. I couldn't take it. It sounded cheap and tinhorn. Those boys weren't heroes, nor even martyrs. They were just dupes about to be sacrificed so that the big show could go on. It wasn't fair to die that way—without even knowing the odds against you. It was treacherous. If they had to die, let them at least know it.

All of Holly's ways and methods had been like this. When had she ever cared a damn for any man's pride? Let them die. What of it, so long as they served the purpose? What did it matter if they were being kidded? Let them think they'd come back heroes! Let them think they'd stand some chance with her—that maybe she'd fall for one of them.

I HAD BEEN thumbing over Luke's pile of photographs sort of absent-mindedly. But suddenly I saw they had been filed in an arrangement contrary to Holly's dictates. I laid them out on the bench, each group one above the other, in the same order as Luke had piled them. Since she had condemned his stuff, he'd evidently gone on studying the prints. Each one was marked with its exact location and depth below the surface.

Perhaps he'd arranged them unconsciously, as one would stack the four suits of a deck of cards. Or perhaps he'd had the germ of an idea. At any rate, those prints in their present order shouted a message as loud and clear as any graph you ever saw. Only little Luke probably hadn't understood.

No wonder he wasn't able to get a shot of the jets or of any bubbles below the fifteen-foot level, *because there weren't any jets! And there weren't any bubbles* below that level!

I marveled at how dumb we'd all been, thinking it was the gas which had impregnated the fluids of the lake, when all this time it had been the fluids themselves which were generating the bubbles, set off, perhaps, by a radium point or small electrical discharge somewhere about that fifteen-foot level, bubbles that expanded like rolling snowballs as they swept up toward the surface.

There in those underwater shots was the whole story, hazy and poorly focused and badly lighted, but none the less obvious. It was the fluid itself which made the gas! A set of figures ran through my brain like lightning. They were from a chart of comparative quantities of gas to fluid for even destructive capacity—carbon appetite—in a scale of varying gas densities. It was a chart compiled by Thompson.

Of course I didn't know what quantities of the gas could be produced from a given amount of the fluid, but there was some crude apparatus in the room and there were a couple of flasks of the lake fluid. I snatched a graded glass tube, half-filled it with the stuff, ran a couple of uninsulated copper wires down into it and stoppered and piped the top like a retort. Then I turned a two-gallon glass jar upside down in the water tank where Luke washed his negatives, and ran rubber piping from my retort down into the water and under the mouth of the inverted jar so that any vapors from the tube would rise and be contained in the jar.

Now for the current. I tried to open the socket of an extension cord but my hand was shaking wildly. Instead, I tore the line from the fixture and bared the wires with my nails and teeth. I twisted them to those from my glass tube and switched on current.

It didn't take much. I cut the juice down to almost nothing. Still the stuff fairly boiled. Evidently the fluid was under almost explosive tension to volatilize, needing only very mild electrical stimulus to set it off.

THE TWO-GALLON jar rocked in its tank. It was half full of gas. I leaped to hold it down. A few seconds more and it was full. I shut off the current and immediately the boiling in my tank ceased. I examined the markings on its side and saw by the fluid's level that less than a twentieth of one cubic centimeter had been used to make two gallons of the deadly gas—two gallons which, unrestrained and free, would expand to make many times as much and be many times as deadly.

Thompson's chart ran through my mind again and I saw for certain, not only that the fluid must be licked, but that it could be licked much easier than in its more expansive gaseous state. It could be licked by its own satiation—by glutting its ready appetite for carbon before it volatilized and developed an appetite a million times greater.

It all seemed so simple that for a moment I had doubts. I unstoppered my glass tube and looked about for some carbon material. There was a can of graphite camera lubricant. I poured the tube half full of it. The black powder grayed, dissolved and the fluid became milky. I poured more and watched the stuff grow still more milky.

I poured another few crumbs of graphite. They did not dissolve, but settled down in the bottom of the tube. The fluid was still thin like water, but milk-white and completely sated.

I was so confident in the success of my experiment that I did not even replace the stopper, but simply thrust the two wires once more into the tube and turned on the current. Small bubbles rose from the point of discharge—and stayed small. With reckless exultation I leaped above the open tube and inhaled. There was just the faintly exhilarating tang of ozone, such as would be normal from any electrical discharge where oxygen was present.

I had it! I looked at my watch. Less than three minutes had passed since I first got wise to those photographs. By now Bull Balfour and Barney Oberteuffer and old Thompson were going to their death—horrible death, on an entirely hopeless errand.

They'd be finding out what I had just now found out—that there were no jets. But they'd never reach the surface alive to tell of their discovery. And—I felt a new thrill of horror—there was a likely chance that when those incendiary bombs did go off, they'd precipitate an instantaneous explosion of that unstable stuff into gas.

I tried not to think about little Luke, I tried not to think of the four men about to die. I tried not to think of what that coming south wind would do to Red City and neighboring towns. I even tried to forget what would happen to all Mars, and to the *Sun Dolphin*, and to myself, if that craterful of soup should suddenly go up like TNT.

My transmitter was useless. I'd have to get my warning through in person, and it could be done. The outer port which locked me in was impregnable, but the other, the one which locked with a key, was not so stoutly made. Just beyond and underneath the keyhole was a steel bolt. That steel contained carbon. Without its carbon it would bend.

I snatched out some more of the rubber piping—the first was gone to whitish paste—ran it well into the keyhole and, using a glass funnel, poured the contents of the second flask of lake fluid into the lock so that it puddled over and about the steel which barred my escape.

Moments passed which seemed like centuries. For once I was almost grateful to the stuff's hellish destructiveness. I pushed hard against the lock. There was no give, but I was confident because I had watched steel die before by this same process. A few seconds later the door yielded with that characteristic grunt of rotten, rending metal.

I raced along the corridor toward the front of the ship. The forward hall was empty except for the broadcaster, whose eye was glued to the porthole as he jabbered into the mike. Outside the main port lock, the whole gang was assembled, including our own outfit, and colonials and brass hats and all species of officialdom.

I gave a leap and careened through them with arms flailing to make a way. Beyond I had sighted four figures in puffy, bulbous diving suits moving toward the crater lake. Four men walking to useless death.

I screamed into my helmet set for them to stop. The leading one faced about and waved me back, then beckoned the others on. My radio was not blanketed now, for I heard curt orders and saw the four men move more hurriedly toward the water's edge. I was almost to them, and calling to Bull Balfour and to Barney to hold everything and wait for me, when I heard that humming in my headset and know I'd been blanketed out once more.

Three of them took separate positions by the crater and, just as I caught up, the fourth suddenly whipped around at me and nuzzled my ribs with the barrel of a cathode gun.

I stared at the weapon and at the clumsy, helmeted figure of the man who faced me, then at the figures beyond him. I recognized the build of Bull and Barney and old Thompson. I looked down at the ugly cathode. "Who are you, sucker?"

Above the drone of the wave blanket I heard his voice: "I happen to be placed in command of this detail. Return to the *Sun Dolphin*." It was a kid's voice, but it was like granite. And I knew right off that he wasn't one of our outfit.

"You *were* in command," I growled, and at the same time struck my fist across the weapon and twisted. His diving gloves were more cumbersome than the ones I was wearing. It was a cinch. I had the barrel pointed steady, right at the base of his helmet.

"Now," I said, "take your orders from me unless you want your head and body in two pieces."

"What do you want?"

"I want to break this business up," I snapped. "And I will, if I have to blow you apart. Keep your hands down and stand still," I added. "This has got to look like it's on the level—just conversation, see?"

He stayed put, but out of the tail of my eye I saw some of the brass hats coming down to investigate. I kept the gun low so they wouldn't get wise. "Now, tell 'em it's all off. Tell 'em—"

But the guy was quick. He barked an order and, before I knew what it was, the other three had started to enter the lake. Then my head rocked as his heavy diving helmet smashed hard into my chest. I sprawled, but kicked out and tripped him so that he fell, too. I saw the other boys were hesitating again. I got between the stranger and the water. "You're not going down and your boys won't go without you, so you might as well give up."

I was talking confident, but bluffing, too, because a lot of the audience had come closer to see what was doing. "It takes four to do that job. I'll stop them if I have to kill you first! Come on!" I seized his belt and shoved him between me and the crowd and let fly with the gun at the rock near his feet. Fragments of stone leaped and richocheted where I'd burned the surface. The next time was closer. I knew his lead shoes were getting hot. "I'll burn

your darn feet off if they don't move." But now he saw I meant business and came along pretty good.

I skirted the crowd and worked my way around toward the tail of the *Sun Dolphin* and past it. Everybody knew by now that it was a holdup and some of the military tried to head me off. They saw I was making for the little rocket plane in which I'd come. But I had all the advantage. They couldn't shoot close for fear of hitting the guy with me, whereas I burned the ground before them every few seconds and kept a barrage of rock splinters sailing in their faces.

I made the kid get in the plane ahead of me while I kept the mob away and made him juice up my coils and get them hot for a quick take-off.

Then they began shooting closer. Some wise guy tried to wing the plane. I didn't dare wait any longer and slammed inside and took off. She was hot enough. We made a swell getaway.

A COUPLE of minutes later the lake and the *Sun Dolphin* were out of sight. I set a beeline for Red City and took a squint at the bird beside me. I couldn't help chuckling. All the wind was out of his sails. I never saw anybody look more defeated.

"Cheer up, punk," I told him. "You didn't do bad. You just don't know any better. Snap on that radio. I want to send a message—a long one."

"Where to?" He coupled his helmet line onto the ship's transmitter.

"*Sun Dolphin.* Get me the First Field Chemical Corps."

He hesitated.

"Step on it," I told him. "You're taking orders now."

After a minute he said he had 'em and I coupled the line to my helmet and told my story, just as it was—of how there weren't any jets in the lake bottom, how the fluid itself was making the gas and how the whole business could be stopped by dumping carbon into the lake—a freighter full of carbon—coal, petroleum—I didn't need to tell them all that. There was plenty of such stuff brought from Earth to do the job in an hour.

Then I rang my buzzer a couple of shorts to show I was through. Bull Balfour's voice roared in my headphones. It gave me a thrill. "Gotcha, Buck, gotcha! Bravo!" I could hear other excited voices and knew the rest of the outfit had got it, too. Maybe brass hats had been able to lead them around by the nose while they were in the dark, but now that they knew what it was all about, the First Field Chemical Corps would deliver the goods and do it fast.

The kid had been listening real quiet. "Now we're beginning to get somewhere," I told him, "but our real job hasn't even started yet. Suppose you fetch me a weather report from Red City."

He tried, but weather reports were not being broadcast from Red City—governor's order. "Damn the governor," I said. "Call the colonial weather bureau and tell 'em who wants to know."

A minute later we got it and it was just what I'd been dreading. "Steady, slowly rising wind from due south." That great outflowing zone of poison from Deep Valley had begun to move toward Red City and its surrounding metropolitan area.

Well, my mind was already made up. No reason for changing plans. One thing had to be done and I intended to do it. But I couldn't help thinking about little Luke again. Just couldn't help it. I said to the punk: "Don't ever let a girl try to mix up in a man's work. No matter how much brains she's got, no matter how good-looking she is and no matter how much you like her. She just don't act like a man. She don't reason like a man, either."

It was hard for me to generalize in particular. "As a girl she'd make somebody a swell wife, but as a pal she's a lousy, rotten, stinking, double-crossing smarty."

The kid said "Yes," and I glared at him wondering what the hell he knew about such things.

Pretty soon we were over Red City. I saw a huge petroleum tanker just lifting out of her mooring toward the mountains. She would be headed for the crater lake and carrying enough carbon to do the whole job with one dose. That was snappy work and it made me feel good.

"Now," I said, "we're going down and pay a call on the governor."

I DIDN'T WAIT for a field crew to come to the plane, but lit out for the governor's office close by. The kid hollered into his

transmiter to wait, that he was coming, too. I looked back, but he was waddling so slowly in his diving stuff that I just laughed and ran on ahead.

When the governor saw me his face registered a dozen kinds of alarm. I could tell that news of me had got on the air and that it hadn't all been nice.

"You here?" he spouted. "The nerve of you! They should have shot you down!" I saw him reach a hand under the edge of his desk, and hit him a good lick alongside the head.

"No bell ringing, guy. We want a nice, quiet, private little talk."

He grabbed onto the back of his chair to keep from capsizing. "Madman!"

"I don't like you, either," I said. "And I've got a right to be mad. Now, mister, are you willing to broadcast your story about that south wind, with orders to evacuate these cities?"

He kept rubbing the side of his face, which was blazing red. "I am not," he says. "And I don't intend to discuss the matter with a madman wanted for violent insubordination and theft."

"Sorry you're not willing, 'cause it's got to be done," I told him and pulled the little gun.

He argued, of course. He said they'd not understand such a sudden contradiction of orders, said he'd just told everybody to sit tight in their own houses until the gas had blown away.

"Listen," I said, "when that gas has blown away you'll have a city full of corpses! I know!"

He said I was hysterical, said the people would never respond. But still he did it. He told them to evacuate the cities. "Where to?" he asked me.

"Foothills of the Northeast range," I said. "Men and boys can make it on foot. As for the rest—truck 'em, rail 'em, fly 'em—you got plenty transportation and time enough if you start now."

The governor looked scared and embarrassed, both. "They won't start. They'll not understand."

But I had that part all thought out. "Just you tell 'em," I said. And he did. "And sound scared." I helped him do that by rubbing the muzzle of my cathode against his paunch. He did sound scared. I made him shout the command into his mike three or four times until he was stammering and shaking and getting his words all mixed up. Then I cut the line.

"That'll be enough, you peace-preaching stuffed shirt. Now get on the telephone. Get the arsenal. Tell them to have a fast rocket plane on this field in five minutes with a couple dozen of those new incendiary bombs."

I had to prod a little harder with the gun barrel, but he did it. Then, for the first time, I noticed the kid had come in and was standing real quiet beside the door. I waited a few minutes until I heard a plane settle outside. Then I said: "So long, guy." But he had slumped down on his desk like he was going to pass out.

I forgot about the possibility of his calling a guard, and made for the door. Somebody said: "Stop!" I caught a glimpse of a wall panel wide open and a uniform coming through.

I didn't stop. The governor yelled: "Get him!" Then my legs wouldn't work and my backbone seemed to curl up and shrivel. Just as my light blinked off I realized it was a "knock-out" ray that had got me. And then I didn't know anything.

SOMEBODY called me a dumb dope and punched and pulled on me and said, "Hurry up!" over and over again. I was walking. I could feel my legs move automatically beneath me. I was sweating awful.

"I've come to," I said. "I've come to, all right, but I can't see anything. I'm blind!"

But nobody answered me. Whoever it was kept pushing me along and steadying me and saying "Hurry up," and cussing real soft and low.

There was a lot of shouting and, although I couldn't hear all of it inside my helmet, there must have been an awful lot of roar and thunder going on, for I could feel the vibration in the ground at every step.

"I'm blind!" I yelled. "Dammit, I'm blind!"

The voice said, "Shut up!" and something jarred against my helmet and rubbed against my face plates. Then suddenly I could see again as a heavy layer of soot was wiped from my helmet glass.

Black smoke billowed around me so nothing was distinct, but I could make out flashes of pale-green that needled the smoky darkness here and there. "Somebody's shooting cathodes," I said, wondering what it was all about. "Gosh!"

I still couldn't think very clear. The guy was pushing again and kept on cussing and called me names and made me hurry. Then I bumped into something. It was a plane. A second later I saw a door open and a man in uniform come out with his hands reaching skyward.

Another shove from behind sent me past him, and first thing I knew I was in the plane. The kid—I recognized him now—was beside me juicing the coils and cussing very low and serious. Then there was a roar and we were off.

As soon as we got above the smoke I looked down and saw where it was all coming from. The governor's offices and adjoining buildings were crumpling and smoking like lard on a red-hot griddle. Civilians and uniformed colonials were running around all mixed up and excited. Suddenly they stopped still and pointed at us. Pencils of pale-green reached up. Some were awful close. The kid gave us the gun and we shot up out of there, zigzagging with so much acceleration that I passed out once more.

When I came to again we had stopped climbing and leveled off. Perhaps the altitude had cleared my head. Anyway, the grogginess was gone. I looked about me and did some quick sizing up of the situation.

"Feel better?"

"Yeah," I said. "I'll take her now. You scram over in back." He didn't argue, just climbed into the little compartment behind me.

"There's a gang of bombs here," he said. "What do we do with them?"

"Know how to use them?"

"Just used one in the governor's office—one I've had on my belt ever since you kidnaped me."

"Much obliged," I said. "That saves me a lot of wondering. But what I mean—can you drop 'em from a plane?"

After a minute he chirped: "There is a trap gadget in the floor, with a sling device."

"O. K., load it up. We're going to try one."

I dipped her nose and cut off the rockets so's not to be such an easy mark for gunners. Then, making a big circle around to southward, I dropped like a plummet.

Red City rushed up at us like hell's own express. "Ready?" I hollered.

He echoed me: "Ready."

There was a set of sights before my cockpit. I lined them on the circular aluminium top of a great petroleum reservoir just at the southern edge of the city.

"Let her go!" I shouted above the siren screech of torn air. A second later, with hardly any loss of speed, we made a long, easy zoom upward and swung out and away from the city.

A BLUE-GRAY plume rose from the center of the reservoir and the whole shining disk disappeared beneath rolling black smoke.

There was a thin stream of traffic running steadily toward the foothills of Northeast Range, but so thin that it was obvious only a few were heeding the governor's command. Well, they'd soon be heeding mine.

I swung back across the city and spilled two more packages, one on the government lumber depot and one on the city granary, both of which would soon be destroyed anyway. The effect was picturesque, but I didn't dare hang around and watch because some of the local gun boys were getting too accurate. One shell burst so close it threw us forty degrees off our course and almost out of control.

It was nearing sunset. We could work on Port John and New Thames a little, then come back to Red City after dark. We did it just that way. We left Port John in a blaze that lighted the night five miles in every direction. Except for loss of property, the fires couldn't do much. But they looked scary and they made a lot of smoke.

I wanted to make smoke just as much as I wanted to scare people, because smoke was the best diluent I could think of for defense against the approaching gas.

New Thames had heard of our operations and had been preparing for us. We were met by a volley of explosives which would have destroyed a lesser ship. Ours was of the best or we'd have collapsed under such terrific pressures. Following that, they sent four planes in pursuit of

us. We ducked out and up, a little faster than they could climb. But we came back after a minute, dropping without power, dark, silent and fast. And presently four towers of flame and smoke rose out of New Thames—out of a lumber yard, a gas plant, an asphalt depot and a small group of oil drums.

We turned back towards Red City, winging off to the south of it to see how near the gas was pressing. Here and there, on our way, we fired some smaller towns and were gratified to see the population leaving in a hurry.

We grabbed a colonial broadcast and found that this attention to the small towns had been our smartest move, for now there was no settlement which felt secure against incendiary attack, and the whole area was being evacuated.

With my power off and no lights I circled above the main arteries leading to the foothills. They were swarming now with fast, orderly traffic. Monorail trains as long as the eye could see were shuttling literally thousands per minute. Giant freighters sluggishly lifted from their moorings burdened with tens of thousands, and the night sky was streaked with transport-rocket flare to and from the Northeast Range.

Everything which would burn in the cities was going up in flame—enough to discourage even the most stubborn and foolhardy from attempting to stay.

The petroleum reservoir on the southern edge of Red City still billowed its masses of black smoke. The wind was rising some and I saw great puffs of the sooty cloud suddenly whiten like ash as the first vanguard of poison gas spent itself upon the flotant particles of carbon.

Wave after wave of white penetrated the rolling blackness down below. Then the kid nudged my arm and pointed. The last files of retreating vehicles and men were already well outside the city.

I grinned. "We've won, feller. We've won by minutes."

No need to check up on the other towns. Red City had been the first in line of danger, so I knew the rest would make out O. K. I relaxed. "I want to go somewhere and be quiet and smoke a cigarette. And I want to talk to a certain party."

The kid had been listening real close to a colonial broadcast. "You know," he said, "that you're wanted by the civil and by the military as a bloodthirsty madman, a thief, an incendiary, a Martian confederate, a kidnaper and a murderous reptile; public enemy Number One."

"Gee, gosh," I said. "Will they get over it?"

"They'll get over it all right, but for two or three days they'll shoot you on sight. After that you're a world hero."

"There's a place I can lay low," I said, "about forty miles west of here—"

WE DROPPED in an easy spiral and came to a smooth, rolling stop. Outside the plane was an unbroken expanse of gray whiteness, starlit, clear to the desert's brim.

Here was no multitude, no glaring lights, sunds, soot nor poison gas. I took off my helmet, threw the ship's port wide open and breathed good fresh air. I lighted a smoke and passed one to my companion, whose helmet was also coming off.

She took the cigarette and looked at me, eyes tired but twinkling with devils in them. "Well, Bucky, aren't you at least surprised?"

For a minute or two I puffed on my cigarette, saying nothing, and keeping a pretty good poker face, but getting a swell close-up view of blue eyes and yellow hair.

This female was one that I had privately damned a thousand times—for her intrigues—for her sacrificing of others—and for her arrogance. Today I had seen her intrigues go haywire, had seen her desperately attempt to sacrifice herself—and had seen her arrogance reduced to miserable defeat. Since then, in the governor's office, she had saved my life. Right now I thought she was pretty swell, but it wouldn't hurt to take her down just one more peg or two.

"Surprised?" I chuckled. "Honey, I've known you the whole time."

UNSEEN TOOLS

By Leo Vernon

The tools of mathemtics can't be seen, of course—and their products, nowadays, can't even be imagined! A fact article on modern mathematical methods.

An object moves freely with constant velocity in 150,000,000,000,000,000,000-dimensional space. Seventy-five quintillion of the dimensions are ordinary rectangular lines, all at right angles to one another. The other 75,000,000,000,000,000,000 represent momenta, all also directed at right angles to one another.

The picture is nightmarish, because it is viewed as a picture. Think of it instead as a method—a tool for obtaining more precise information, and it is less terrifying. Mathematics is more easily understood from that viewpoint.

Tools must be used to shape machinery of all kinds. The machine doesn't form itself out of naturally occurring minerals. An engineer designs the machine, but tools must be used to mine the ore, smelt the metal, cast it into form, and finally cut or stamp the metal to correct shape. Experts invent the necessary tools; tool and die makers are an essential part of any industrial set-up.

The mathematician invents and makes the tools which are used to study and dict happenings in chemistry, physics, astronomy, and any other science which has developed sufficiently to require exactitude in stating its ideas.

When cannons were first invented, it was a serious problem to try to predict where a cannon ball would land. Worse, it was impossible to point the gun so that the ball would be fairly certain of landing anywhere near the enemy. Mathematicians invented the tool of analytical geometry, and used this tool to solve the problems of exterior ballistics with the accuracy needed at that time. More advanced tools are used now in ballistics, since the shell travels far beyond the sight of the observer and is affected by wind, temperature, rotation of the Earth and other factors.

Scientists must use the tools of mathematics to simplify and compare experimental results, or to learn how to obtain new results. The equations and concepts are just as much tools for the minds of scientists as a calculating machine is a tool for a mathematician.

Some rare individuals may have the type of mind which cannot grasp the ideas of mathematics. The great majority will have no difficulty if they learn to look at or use mathematics as a tool, and if they learn one fundamental consideration.

It is not necessary to have a neat geometrical or mechanical picture of the mathematical tool.

It is so much necessary to learn this, as to unlearn the opposite. Most of us have been taught from infancy to think in terms of physical or mechanical pictures. We try desperately to visualize any new idea in terms of familiar forms. The job of learning is to banish these pictures from our minds, and to use the tools simply as tools.

The visualization works all right for some things, as plane geometry, but even in simple solid geometry some problems slip away from our grasp. It is easy, for example, to close our eyes and picture a cube, bounded by six squares all set at right angles to

adjoining sides. It is not difficult to visualize just how many ways it can be turned around or rotated so that it will always occupy the same region in space; just turn at ninety degrees in any direction perpendicular to one of the sides or faces.

Now try to picture a regular icosahedron with twenty faces, all identical equilateral triangles set at equal angles to adjoining sides. It is a struggle, but it can be visualized. How many ways can it be rotated always to occupy the same position in space, and through what angles? Some new tool which doesn't require forming a mental picture is very welcome now. The tool is available, and gives the solution readily—group theory. The same tool is used by physicists in studying and predicting infrared spectrum of molecules, or by mathematicians in deciding what kinds of algebraic equations can be solved.

The mathematician is not limited to tools that can be easily seen, or visualized. He uses what is most convenient for solving his problem, as the 150,000,000,000,000,000,-000-dimensional space. It is impossible to picture a number of that size, let alone a space with that many dimensions. Yet the use of equations that seem to describe such a spacetime continuum makes it possible to solve problems concerning the properties and behavior of gases.

MANY mathematicians and physicists believe that science will advance more rapidly as it gets rid of many of the old mechanistic theories and pictures. The ether was a beautiful picture while it lasted. Space, everything, filled with a substance which vibrated and transmitted light, electricity and magnetic force. Yet the tools of mathematics showed that if there is an ether it is delicate, frothy, infinitely rigid, perfectly tenuous, very dense and perfectly impalpable. Visualizing such a substance was an impossible strain, and the ether was unobtrusively dropped out of textbooks and equations. The tools worked better without a mechanistic background.

Another clear-cut picture was the old Democritan atom—a small solid sphere of matter. Then the electron was discovered and physics tried to picture the Rutherford-Bohr atom with a solid nucleus and little solid particles revolving around in neat orbits like miniature solar systems. There were difficulties with the picture because there were good reasons for the electrons to refuse to stay in set orbits. They were rotating, but were supposed to be losing energy by radiating light. If that were a true picture the electrons would spiral down to the center or nucleus in a very few years and the whole Universe would collapse on itself and vanish.

Then deBroglie and Schroedinger stopped thinking in terms of macroscopic, mechanical counterparts and wrote equations representing wavelike motion for the atoms and electrons. The theory worked beautifully. for many things. It is still too mechanistic, though. Heisenberg's matrix theory and Dirac's abstract waves, still less mechanical in nature, give more accurate results.

It even becomes absurd to ask certain questions, such as—How big is a quantum? A quantum is a small unit of energy. Energy and mass are interchangeable. Then how large, or how big, is a quantum? It can come out of the interior of an atom, or hit one electron and one only. Or it can be as big as the reflecting mirror of the new two-hundred-inch telescope. Such questions are meaningless when we try visualization. Yet they are meaningful in that they show the impossibility of tying down one certain quantum, the uncertainty of microscopic quantities or qualities.

Mathematics has developed the tools to discover and to explain or interpret such matters. The tools can be used for prediction, or to lead the way to proof, provided there is experimental data available as raw material for the tools to work upon. Theoretical or mathematical science needs the experimental information to manipulate.

The best known example of prediction from experimental data is the independent work of Leverrier and Adams. The implements in the form of celestial mechanics had been developed by Laplace and Newton. Numerous astronomers had shown that something was perturbing the orbit of Uranus. Using the data on Uranus as the stuff to work with, and the tools of mathematics, both Leverrier and Adams independently predicted where the trans-Uranian planet Neptune would be seen, if a powerful enough telescope were used. Neptune was discovered exactly where they had predicted. The discovery of Pluto followed a nearly similar course.

A still more important development, not just the discovery of a new mass in inter-

planetary space, but one which affects everyday life, began in 1861. James Clerk Maxwell took the data of Faraday and other experimenters and began developing the tools to work with this information. In three years' time the tools were completed and used to predict electromagnetic phenomena. Instead of picturing electricity or magnetism in space as a flowing liquid, Maxwell found the date could be fitted into equations which represented electromagnetism as wave motion. No one had ever thought of waves in space. Not even Jules Verne at his wildest had been able to write such unbelievable fiction. Yet this fantasy worked.

Confirmation came in 1884, eight years after Maxwell was dead, when Heinrich Hertz produced and measured electromagnetic waves. Another ten years, and Lodge had transmitted the waves through space for a distance of one hundred and fifty yards. Eight years later, in 1902, Marconi sent a radio message across the Atlantic, using an application of the preposterous seeming tool mathematician Maxwell had invented.

The tools of mathematicians now are no more extravagantor ridiculous than the one invented and applied by Maxwell in 1864. They have to be less mechanical, more impossible of visualization, because of the inexpressible complexity of some of the problems facing present-day scientists and mathematicians.

There are problems awaiting to be solved right now which would require a lifetime of work by any one mathematician. They are postponed until more suitable methods are invented, new applications of old tools discovered. Many of these have developed over a period of centuries.

A SIMPLE PROBLEM now is the motion of a single particle affected by gravity. Even that was impossible until Newton discovered the means of expressing gravity mathematically and invented tools which made the calculations possible. Now it is done readily, a problem in three dimensions. That is, the position of anything, the particle, can be described at any time by using three rectangular co-ordinates or distances to describe its position. The three quantities x, y, and z will locate any point in space.

Now imagine a two-body problem—two particles in space attracted to one another by gravity, or electrical force, or any other force. We need three co-ordinates to describe where the first one is: x^1, y^1, and z^1, and another three to describe where the second is located: x^2, y^2, and z^2. We need a set of six different co-ordinates to locate the position of both particles.

This problem can be solved, without too great difficulty. But we have used six co-ordinates, what is essentially a six-dimensional space. If no attempt is made to visualize the problem as two particles in three dimensions, and only six dimensions used, the problem is simpler. One particle in the six-dimensional space describes the motion of the two particles, each in three dimensions. Every point in the six-dimensional particle may occupy is described by the six distances, corresponding to the three each for each three-dimensional object.

This six-dimensional problem is often simpler than the three-dimensional. The attracting force, gravity or some other force, may be of such a nature that the particle merely slides over the surface of a six-dimensional sphere, following a great circle route in many dimensions. It becomes an easy problem, but don't try to picture six rectangular axes, or six straight lines all at right angles to one another. It can't be done, but the problem can be solved easily.

The most famous of all mathematical problems, that of three bodies, cannot yet be solved generally. This is the problem in which three particles attract one another according to the Newtonian law, so that between each pair there is an attractive force proportional to the product of the masses of the particles and inversely proportional to the square of the distances apart; they are free to move in space and are in motion at the start of the problem. How will they move, what orbits will they follow, at any future time?

There are two important examples of this problem: the motion of the Solar System, as the Earth-Moon-Sun trio, or the motion of electrons in the helium atom, the second from simplest of all atomic structures.

The problem can be solved for some few special cases, as the equilateral triangular arrangement in which all three particles remain always equidistant from one another. An example of this is the two sets of Trojan planets, those which form the points of a

triangle sixty degrees ahead or sixty degrees behind Jupiter in its orbit. There is also the theoretical case of a collinear solution, in which all three particles always remain in a straight line, or the possibilities in which two or all three of the particles collide.

(The Trojan planets, which were predicted by Lagrange in 1772 as being theoretically possible, remained as interesting hypotheses until 1906. At that time the first Trojan planet, 588 Achilles, sixty degrees ahead of Jupiter was discovered. Since then several others have been found, as 617 Patroclus sixty degrees behind Jupiter in its orbit.)

The general problem, though, cannot yet be solved even using nine-dimensional space in terms of any mathematical functions or ideas that have yet been invented. But the mathematical tools for the study of the problem prove that it can be solved, or that the tools needed can be invented. In 1906 and 1909 K. F. Sundman of Finland was able to prove that a solution of the equation exists, and that it has finite calculable values, provided we can find the tools with which to determine the solution.

This may seem to be another one of the farfetched mathematical problems with no practical value, but mathematicians have been trying for centuries to solve it. Hard-headed, practical governments have offered prizes of thousands of dollars to the mathematician who either could solve it or find a still closer approximation to the solution. A solution is necessary to make accurate prediction of tides. Newton spent years trying to get closer approximations. At the beginning of this century, it required thirty years' work to come close to the true values. This decade, a still closer approximation was obtained in two years' time using better tools and newer types of calculating machinery.

Beyond the three-body problem is the n-body problem, the problem of any number of particles greater than three. Still different tools are necessary in this case. One type of this problem arises from the study of gases. One cubic centimeter of helium gas contains about 2.7×10^{19} atoms of the gas. We want to know the future behavior of the gas.

Each atom requires three co-ordinates to describe its position, and three more to tell how it is moving in space; six for each atom. To state the problem we need to use one particle moving in 150,000,000,000,000-000-000,000-dimensional space. This problem, strangely, can be solved almost as accurately as some three-body problems, provided we use statistical methods.

It is impossible to tell how long any particular man twenty-five years old will live, but very accurate mathematical tools will tell how many men of twenty-five out of each hundred thousand will live to be eighty years old. With quintillions of dimensions and many cubic centimeters of gas, it is possible to predict statistically how the average cubic centimeter of gas will behave, and thus the probable behavior of a large sample of helium.

Even newer tools must be developed by mathematicians, concepts which will challenge the credulity of the most hardened individuals. Ideas seeming so reasonable that we have come to accept them as law can be questioned as readily as the medical efficacy of the unicorn's horn was challenged.

For twenty-two hundred years it was accepted that parallel lines must never meet, until it was believed that a geometry must start with that postulate as its basis. Lobatchewsky, in the early part of last century, challenged this axiom. He assumed that parallel lines may meet, and developed completely new geometries, new tools with which to reason and develop science. Minkowski and Riemann and Klein continued the work. Einstein developed the theory of relativity.

An unchallenged idea, one that seems easy to visualize, or to see, lasted for twenty-two centuries. A mathematician hunting for new tools to shape the facts and observations made around him asked if what we saw was necessarily the thing to use. Non-Euclidian geometry was the result.

Einstein, using the tool, predicted in 1915 that light would not necessarily follow a straight line through space, but would be bent by gravity. This apparently fantastic tool made the still more fantastic prediction that gravity, a force connected with mass, would distort a beam of light, an electromagnetic vibration in "ether." In 1919 scientists traveled half around the world to test the theory during a Solar eclipse. They found that the light from stars back of the Sun was bent as it passed close to

the Sun through the strongest gravitational field within our reach. The unreasonable geometrical tool had developed a ridiculous and unbelievable theory, but one which checked with experimental measurement.

As if that were not enough, Einstein's theory also explained the unaccountable misbehavior of the planet Mercury which always swung a little bit too far as it came to the innermost point of its elliptical orbit. That was easy. When an object moves faster it behaves as if it were heavier. The immutability and unchangeable character of mass had been challenged successfully.

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OTHER CHALLENGES to the reasonable mechanistic-minded person came in the fields of atomic science. The discovery of the electron had disturbed the repose of those physicists who, in 1890, said that all there was to be discovered had already been discovered. Physics, so they said, is a complete science, except for extending the theory to another significant figure and rounding off a few rough edges.

The electron discovery required new methods. Rutherford provided the Solar System model for an atom, and physics was stirred still further from its already precarious balance because the theory explained quite exactly only about one quarter of the previously unexplained knowledge about hydrogen.

But there were ninety-one other elements still inexplicable, and the Solar System atom was unstable, whereas hydrogen seemed quite stable to the experimentalist. It was necessary for Bohr to assume that the electrons revolved in fixed orbits, and were "forbidden" to move in others, or to transfer to certain kinds of orbits.

Schroedinger's wave mechanics settled many of the problems, but raised many more questions that still wait answering. The equations of the mechanics were of the same general shape as the equations which describe the motion of, say, a vibrating string. They had the characteristic that only a limited number of solutions were possible, just as in the case of a string which can vibrate only with a certain tone.

This explained the previously forbidden positions or actions of an electron. There simply were no solutions at those points in the atom. They were nonexistent. But now it was impossible to visualize the electron. One scientist tried to by describing the electron around a hydrogen nucleus as a quivering, doughnut-shaped mass of mush. He didn't try helium, which requires a six dimensional doughnut for the two electrons.

The mathematics was so accurate that it was found that a relativity correction must be applied, similar to the correction for Mercury in its orbit around the Sun. This had been attempted in the Bohr atom, with indifferent success. Now, when the mechanical picture of a revolving electron in an orbit was abandoned in favor of a vibration, it was necessary to apply a mass correction, as if the vibration were a moving massive object.

Other completely unexpected properties were discovered after the new tool was in use. The hydrogen molecule, for instance, had always been thought of as simply two hydrogen atoms hooked together in an unknown manner. When it was discovered that the nuclei of the atoms behaved as if they were solid particles spinning on their axes like planets, the idea developed that in some molecules the nuclei might spin both in the same direction and in others spin in opposite directions. This would result in two different molecules with different specific heats, in a ratio of 1 : 3. In 1928 Bonhoeffer tried the experiment, and separated the two kinds of molecules: ortho- and para-hydrogen.

A still more abstract, nonmechanical expression of the atom was developed by P. A. M. Dirac using Heisenberg's matrices and wave equations which did not represent actual waves but purely abstract quantities. The solutions of the equations described experimentally measurable properties of electrons.

In the spring of 1929 Dirac told in his lectures that these solutions gave twice as many answers as were to be expected. The tool produced results which were never anticipated. Half of the answers fitted perfectly what was already known about the electrons. The other half described an unknown and inconceivable object, an electron of the same mass as the ordinary electron, but with a positive electrical charge.

Dirac himself appeared almost apologetic about the matter, but was already developing the ideas of positive charges being simply the lack of negative electricity. He insisted the tools were used correctly. It couldn't

be a flaw in the mechanical picture, as in the case of the unstable Solar System picture of the atom. This was not a mechanical model but a purely abstract mathematical tool.

In August of 1932, C. D. Anderson at California Tech found the photograph of the track of a positive electron. He hesitated for several weeks, but finally announced his discovery. A few months later many physicists had produced and studied the new positron.

The neutrino and mesotron are largely the offspring of mathematical tools, still being studied by physicists with the question of actual existence barely confirmed. They are small, unimportant consequences of theoretical mathematics and mathematical physics, but they bring the goal of atomic energy immeasurably closer by giving us more detailed information of the internal make-up of the atom.

These may seem far-off, impractical and unusuable, but remember the series: Maxwell and electromagnetic wave theory to Hertz and elecromagnetic wave measurement to Marconi and radio. These changes may have occurred in rarefied branches of mathematics, or possibly even in geometry, for, after all, Euclid was collected together twenty-three hundred years ago. It is still possible to imagine the series of discoveries: Thomson and the electron to Rutherford and Bohr with the Solar System model to de Broglie and Schroedinger and Heisenberg to the abstract Dirac atom leading to atomic energy. Not forgetting ever the Lobatchewsky to Einstein series which ties in with the new abstract atom.

But a field such as arithmetic and algebra seem well fixed, grounded in good common sense dating back to the fifteenth century. That would appear to be unchallengeable, impervious to change.

AN IMMEDIATE thought of possible improvement in arithmetic would be the change from decimal to duodecimal system, with the especial advantage of ease in factoring and lack of simple repeating decimals. The fraction $\frac{1}{3}$, for instance, would be a simple decimal, 0.4. Vingtesimal, or even sexagesimal systems are equally possible and have special uses.

Fundamentally, though, all these systems and the algebra we ordinarily use are derived from one basic concept—numbering and counting in units of fractions of units. In algebra we may be taught that x or q may represent anything, but our teachers, and we with them, unconsciously think all the time, "yes, any material, mechanical thing such as sheep, or apples, or dollars."

Mathematicians have challenged that idea. Why use a mechanistic concept in algebra or arithmetic? Throw it away and use a more general one.

We obtain what looks like a mess at first glance, worse than non-Euclidian geometry, but in reality beautifully simple and symmetric if the idea of mechanical units is disregarded. There are an infinite number of algebras and arithmetics possible, with our common variety merely a special case in which we assume the Ps and Qs are real numbers or things.

We use a number system with an infinite number of units. There is no need here to argue what kind of an infinity, or how large an infinity compared with other infinities. It can simply be called an infinite set of numbers. Need this always be the case?

Can't we imagine a finite group of things, and build a logical consistent arithmetic, algebra and calculus around the group? We can state certain rules in advance, such as that the product of any two things in the group shall always be some other member of the groups, and that there shall always be one number of the group which is an identity, similar to unity in the ordinary number system.

The members of the group may represent anything we want them to: operations of a familiar nature such as multiplication, division, addition, subtraction, integration, or combinations of these operations. They may stand for rotations of an icosahedron or rearrangements of the order of something.

One group arises from the fact that the three letters abc can be written in six different orders: abc, acb, bac, bca, cab, and cba. Directions for rearranging the first order abc to form any other order are plainly to be seen. To change abc into acb, leave a as it is, but interchange b and c. This can be written as (bc) and read: b changes into c, c changes into b. To obtain the order bca, the directions would be written (abc) which reads: change a into b, change b into c, and change c into a.

There are only six possible changes:

(bc), (ab), (abc), (acb), (ac), and I, which makes no change at all, an identity change. The first five could be called A, B, C, D, E for convenience.

These changes can be made one after another. The first rearrangement might be (bc) or A, and the second (acb) or D. The result of doing these two rearrangements in order is the same as starting out to do (ac) or E. This can be written down more easily as $A \times D = E$. But the startling feature is that $D \times A = B$.

A complete multiplication table can be worked out for this group of six generalized numbers. It may seem amusing, just a childish pastime, yet the group theory of substitutions is a powerful tool in making other mathematical tools. Instead of rearrangements just of letters, it might be rearrangements or rotations in space of an icosahedron. The results of these rearrangements, one after another, are useful information for the crystallographer, for the mineralogist studying the strength of new types of alloys, for the physicist studying how groups of atoms are held together, and what forces are necessary to make them stick in certain molecules. The mathematician uses a similar type of group to predict whether an algebraic equation can be solved at all, or under what conditions.

ANOTHER extension of this type of abstract algebra abandons even the idea of operations for members of the group. Let the letters or symbols forming the group stand for tables of information. They may be ordinary appearing tables of numbers, or equations, or operations or even ideas, as long as the tabulated material is arranged in logical order and in mathematical terms. The tables don't need to be square like determinants but can be rectangular, and may have an infinite number of rows and columns.

In 1858 Cayley, who invented n-dimensional geometry as a mathematical tool, also discovered the algebra of matrices. Other mathematicians added to the subject, and advanced the arithmetic of tables of information to matrix calculus and even complex mathematics.

Using tables of information, tables resembling pages in a book of logarithms, mathematicians were able to multiply, divide, integrate and differentiate equations in which the Xs and Ys and As and Bs were merely tables called matrices.

In 1925 Heisenberg took this tool and made up matrices listing various things—sometimes data about the atom, other times mathematical operators describing things to be done to the electron, and in still other cases simply tabulating mathematical statements of ideas and information about the atom and electron. He did his mathematics with these matrices, using matrix algebra and calculus. After getting his final matrix answer, he wrote down the table of answers which the information represented, and had new and previously unknown information about the behavior of the atom.

It was by a combination of this with the wave theory that Dirac was able to predict the positive electron nearly four years before it was found. Dirac used the matrices as parts of the wave equations. Let the mechanically-minded person try to visualize a multi-dimensional vibration of tabulated information. Yet the use of such a tool predicted the positron and has brought us still closer to atomic energy.

The symbols do not need to represent just physical quantities or operations or tables of these things. They can represent ideas which do not have to concern physical quantities. They can be about anything. Symbolic algebra can be applied as symbolic logic to discuss anything the imagination of the mathematician can envision.

Just recently C. E. Shannon at Massachusetts Tech has used symbolic algebra in the form of symbolic logic to study and simplify extremely complex switchboards and wiring diagrams. Let the symbols represent switches, resistances, any feature of an electric circuit. Instead of multiplication and other ordinary operations, use signs to indicate operations. One sign may represent a switch closed. Another sign a switch open, or more precisely, not closed. After writing out the entire set-up in the symbolic forms, similar terms are combined just as in ordinary algebra. Then, if it is found that the symbol for some one switch which says "yes, closed" is right beside the symbol for the same switch with a sign saying "not closed," they cancel. The switch makes no difference in the circuit and can be removed.

A still more fantastic application has been found in the legal profession. An insurance company recently worked with contacts which ran on, page after page of fine type.

No lawyer or judge alive could keep track of everything in those legal phrases and know for certain that there was no contradiction or absurdity in the contract.

Symbolic logic, of a type that could be understood and followed by anybody who has studied high-school algebra, was used to reduce the contract to basic ideas. The symbols were combined, canceled, rearranged in logical order, and then reinterpreted into legal phraseology, to produce a much shorter and fool-proof contract.

MATHEMATICS does absurd sounding things, talks of fantastic impossibilities, but they are absurd and fantastic only if attempts are made to picture them as physical realities. Mathematicians use these tools to solve problems of greater and greater complexity.

Five centuries ago ordinary commonsense people laughed at mathematicians because they had such a nonsensical idea, that of introducing a tenth number—o. There were already symbols for 1, 2, 3 and so on. It was ridiculous to think of using a symbol for nothing. Nothing was just nothing. Why bother to write it down and needlessly complicate the system?

Mathematicians went right ahead using their preposterous symbol for nothing, and were able to do multiplication and addition in a hundredth the time it took commonsense people to do the same problems. The use of the symbol for nothing was a tool which caused some mathematicians to be accused of witchcraft, but now everybody is acquainted with that tool. It seems natural.

Mathematics has developed many other tools since that time, and they need still more tools and newer ideas. There are new fields of science to be studied, particularly the social and biological, which need better tools in statistics. There are problems in the physical sciences which can't be solved until new tools are invented. The three-body problem is one which has very practical application for everybody.

There are problems that are as yet mainly mathematician's problems, since they have to do with the tools themselves. Squaring the circle or trisecting the angle are of minor importance, and can't de done anyway by Euclid's rules. Fermat's problem is interesting, or Russell's paradox, or the idea that an arbitrarily short segment of line has just exactly as many points on it as there are in an infinite space of infinite dimensions.

These tools and problems will gradually become more available and more readily understood as we give up trying to make mechanical models of every idea. There is now no reason why symbolic algebra could not be taught in the high schools as part of a regular algebra course.

THE TESTAMENT OF AKUBII

By Norman L. Knight

In some regions of space, there may be stars and planets that have no oxygen. If men should run out of oxygen in such a region—

Although the tale of the voyage made by Greenbough and Akubii is not in itself incredible, students of extramundane affairs heretofore have regarded its claim to verity with skepticism. There were several reasons for cataloguing it as a bit of spaceman's folklore—a yarn fabricated somewhere between the stars in a forecastle bull-session. In the

first place, there was no evidence to indicate that two such individuals as Greenbough and Akubii had ever existed and documentary data as to their space cruiser, the *Peregrine*, likewise were completely lacking. Secondly, the earliest known written account occurs in the "Galactic Chronicles"—that vast, heterogeneous compilation undertaken—but never completed—by Ilrai the Younger. This almost legendary Martian historiographer combined an amazing literary activity and insatiable curiosity with a weakness for good stories incompletely verified. Furthermore, there is a suspicion prevalent that the narrative may have been inserted in the "Chronicles" after 2650 A.D., the approximate date of Ilrai's demise. Perhaps it was exhumed from the staggering mass of Ilrai's unpublished memoranda which he left scattered over a dozen planetary systems, but this never has been proven.

The sulphurous planet described by the hypothetical interpolator does actually exist as an attendant world of a waning red star in that outreaching tentacle of our galaxy known as the Orion Peninsula. Generations of astrogators have designated that star as Akubii and have referred to a certain atomic transformation as "the Greenbough reaction" in stubborn disregard of the scholarly objections of historians.

The alleged source of information regarding the last cruise of the *Peregrine*, according to the "Chronicles," was the photoscript log of the vessel. It is asserted that the cruiser was found revolving in an orbit around Aldebaran, filled with a gaseous mixture of nitrogen and helium under a pressure of two atmospheres—Earth standard—and containing the mortal remains of but one person—Greenbough, dead in his bunk. No convincing clue is given as to the fate of Akubii.

On the latter point the writer has based a contention of long standing that we were dealing with a narrative of fact. The creator of an imaginary adventure would not devise a mystery and then leave it unsolved.

But we may affirm now that Greenbough, the Earthling, and his Martian companion have been identified as real individuals—the first Solar pioneers to attain to one of the remote outposts of our star swarm. The archæological section of the Cosmographic Survey has recently discovered and investigated the remains of an ancient spaceport on the world Aldebaran III, where they have brought to light not only the log of the *Peregrine*, together with other pertinent records, but a "graveyard" of old spacecraft as well—including the *Peregrine*—in surprisingly good condition.

It seems that the spaceport on Aldebaran III was an ill-conceived venture which was hastily abandoned after a few years for reasons which need not concern us here. Both Greenbough and Akubii were natives of a Solar colony on a solitary planet accompanying the star Delta Prime in the Hyades. It was here that the *Peregrine* was constructed. Subsequently this world and its colonists were engulfed by the explosion of Delta Prime into a nova, and the local files of statistics relative to the two navigators and their vessel likewise vanished in the holocaust.

Obviously the nameless author who may have amended Ilrai's opus had examined the log of the *Peregrine*, but knew nothing of that which modern archæologists have found in the false bottom of Akubii's bunk. The account which follows is a modification of the one in the Procyon edition of the "Chronicles," the principal change being the inclusion of the testament of Akubii.

GREENBOUGH scrutinized the conning screen which constituted, for the *Peregrine's* navigators, their sole visual contact with the external Universe. It was an amplifying screen, rendering visible celestial objects too faint to be perceived by the unaided eye, and could be connected with anyone of a battery of strategically placed televisors in airtight vacuum cells behind massive porthole plates of silicoid. If one of the plates cracked—as occasionally they did—the *Peregrine* lost none of her precious freight of air.

"This is it," announced Greenbough. "The edge. The jumping-off place. The spot where a wise navigator would begin to think of turning back, even as we are. Some day, other ships—"

Near the lower rim of the stereoscopic screen swam the image of a dying sun, sullen orange-red like a ball of glowing iron. The image had depth and solidity—one might have thought to pluck it from the screen—and stood out with stark clarity against a background of ultimate black so intense that it appeared to vibrate with an obscure energy. Around the glowering, moribund sphere a sprinking of farther stars blazed with untwinkling brilliance. And beyond these marginal suns of the Galaxy a host of outer galaxies was strewn across the field of infinite blackness as profusely as daisies in a meadow. The nearer ones were clotted nets and clouds of radiance—roseate or greenish or serene white; those more distant were mere misty blobs and dots of light.

"The wonder of them never grows old," continued Greenbough. "Look at them! Universe upon universe, as multitudinous as our stars. Endless legions of universes, filled with endless swarms of worlds and life! It must be so! I can feel it."

Akubii, Greenbough's un-Earthly companion, responded to his thought—not

vocally, but through a mutual harmony of minds.

"For one who stands near the brink of death you are strangely unconcerned," observed Akubii. "We should concentrate upon the problem of our decarbonizer and our air supply. We must search for a planet and hope that it has an atmosphere."

(*Here the original narrative enters into a description of Greenbough which we omit.*)

Those who have never seen a Martian should be informed that Akubii resembled the Earthling in form more than one might deem probable. He was greater in bulk and stature but he differed primarily in that his organs and tissues were—in varying degrees—transparent. He seemed a creature of colored glass, with a crystalline epidermis through which his inward motions and pulsations were clearly visible. Akubii's head was lobed and segmented internally, suggesting the structure of an orange; and embedded beneath the glassy integument of each lobe was a piercing, inscrutable eye. His skull was a chitinous gridwork whose apertures revealed the convolutions of a blue-tinted brain—blue, because Akubii's blood pigment contained copper instead of iron. Instead of nostrils he possessed spiracles in his chest, and his mouth was an inarticulate orifice in his midriff. His arms were bifurcated near the shoulders, many-jointed, terminating in clumps of boneless retractile fingers tipped with close-set rows of minute suction cups.

"What we need is a compact device to synthesize oxygen from carbon, but we don't have it," reflected Greenbough. "So we're at the mercy of the decarbonizer. What did the last check-up show?"

"Our worst fears are confirmed," Akubii replied. "The process appears to be self-catalyzing and cumulative. About one part of oxygen in ten thousand is being transformed into helium, an increase of two percent over the previous determination."

FROM the moment that her air renovating apparatus had shown symptoms of abnormal behavior the *Peregrine* had been decelerating toward the dusky-red star. At her vast distance from surveyed and charted regions she had no choice save to set her course for the nearest possible source of oxygen. Although the ship carried reserves of the liquid gas they were strictly limited. Everything in her interior had been designed and redesigned to meet an inflexible standard of utility and compactness. Items of equipment had been relentlessly eliminated as nonessential. The vessel in transit was a little sealed world from which nothing escaped save the radiated energy of her driving spacewarp and a slight unavoidable loss of heat.

Not even her refuse was ejected. It was distilled, baked, incinerated until it was decomposed into water, oxygen, nitrogen, and a carbonaceous residue. The latter, in turn, was fed into her power plant, where it entered a miniature inferno of disintegrating osmium and contributed its mite of power as it vanished in a blast of pure radiant energy. The air within the ship circulated constantly through the decarbonizer, which forcibly disrupted carbon dioxide and delivered the carbon as an impalpable black dust. The erratic transformation of oxygen into helium by this apparatus, although slight at the moment, obviously was a danger of the first magnitude because of its inexorable tendency to proceed ever more swiftly.

The *Peregrine* continued to decelerate until her speed was merely meteoric, plumbed the void with a thermoscopic detector until she found a radiating body relatively near at hand but still invisibly distant. She directed herself toward this unseen object, finally picked it up on her conning screen. It was a globe of planetary size showing a gibbous phase to the *Peregrine*—dim and coppery-brown in the faint light of the expiring sun, like the Earth-moon in total eclipse.

The vessel entered a perceptible atmosphere at an altitude of four hundred miles, and while she descended along a globe-girdling spiral the navigators sampled this atmosphere—at first hopefully, then with anxiety.

"Not much encouragement here," decided Greenbough after the analysis of the third sample. "Methane and ammonia, fair amounts of hydrogen sulphide and a trace of cyanogen. But there are heavy clouds down under and perhaps we shall find water."

An immense crinkled pavement of clouds now lay below them, tinged a dusky carmine with shadows of purple and indigo under the dim and rufous sun.

"I doubt that those are clouds of moisture," Akubii declared. "Probably they are something else."

"Perish the thought!" protested Greenbough.

But Akubii's surmise was correct. The clouds proved to be vapors of carbon disulphide, ammonia, and the higher sulphides and carbides of hydrogen.

And as the *Peregrine* sank through the vapors they condensed on her hull and befogged her televisor ports with an oily dew, so that she was constrained to ride the clear atmosphere beneath the clouds until her ports had cleared themselves by evaporation. Now the navigators found themselves afloat in a strange gloom of encrimsoned violet under a cloud-canopy of midnight-purple, thinning in patches to a wine-colored luminosity. The canopy parted as they watched, and revealed the gigantic globe of the sun filling a tenth of the heavens. Seen through the alien atmosphere it was an angry crimson with a purplish cast. Beneath was an expanse of ocean like a sea of dark blood, its billows marked by long stripes of violet shadow.

Astern, a distant coast thrust mountain peaks above the horizon—peaks of phosphorescent minerals which glowed with a nebulous pallor against a sky of stormy purple cumuli.

GREENBOUGH brought the cruiser to rest upon the ruddy sea, and Akubii withdrew a sample of the fluid. He reported that it was essentially carbon disulphide containing cyanogen, methane, and dissolved sulphur, at a temperature of forty-two degrees below zero centigrade, and spectroscopically free of oxygen.

"To us, this is an utterly inhospitable world," remarked Greenbough when he had received this information. "It is deadly and repellent, yet it has a strange sort of lifeless beauty. It is magnificent but dead."

"It demonstrates that there are local irregularities in the distribution of matter in the Galaxy just as there are in the composition of planets, and it would not be inappropriate to name it Sulphuria," commented Akubii. "But you are overhasty in calling it dead. Look yonder."

The conning screen showed a trail of V-shaped ripples traversing the liquid surface as if in the wake of some swimming creature. It passed swiftly beyond the field of vision.

"There is life here!" Greenbough exclaimed. "Do you suppose that there may be intelligence also?"

Akubii slowly rotated the optical turret which was his head and thoughtfully regarded Greenbough with his battery of eyes.

"If this world does harbor rational creatures," his mind said to Greenbough's mind, "and if it does contain some slight amounts of oxygen which they have had the wit to discover, and if we can make ourselves understood by them—it may be that both of us shall return alive to the Hyades. Otherwise, even if we turn back now, there will be scarcely enough air for one before the journey is finished."

The remainder of the thought was hidden from Greenbough. He lifted the cruiser from the sea and turned her prow toward the fluorescent mountain range.

THE FOOTHILLS of that range rose from the sultry crimson ocean in red-glittering cliffs of pyrites streaked with luminiferous veins. As the voyagers drew nearer they descried a curious structure perched upon a sparkling promontory. It suggested a cluster of the strange formations which one sees in caverns yet it had the regularity and symmetry of design. Under the ruddy illumination it flashed with a glassy sheen. Both observers entertained transitory hope that it was constructed of ice.

Greenbough emerged, protected against the lethal atmosphere by space armor of nich-thick reinforced synthetic rubber plated with a reflecting film of aluminum, and split off a fragment of the material. It fractured with an electric crackling. A rapid examination aboard the *Peregrine* quickly identified it as halite—rock salt—a strong and durable building material in that waterless world. The edifice covered many acres; it reared slender two-hundred-foot towers fancifully carven and pierced, and inlaid with galena.

The descent of the *Peregrine* roused the dwellers in the towers. They came forth from their aeries like shoals of aerial jellyfish, translucent buoyant gas bladders with trailing manes of knobby tentacles. They swam and hovered above the cruiser, propelling themselves by the fluttering of filmy

appendages. A glowworm flickering of lights rippled along their tentacles in an ordered rhythm which inescapably suggested telegraphy.

Neither Greenbough nor Akubii could establish an intelligible mental contact with the minds of these creatures; the very fabric of their thoughts was alien. The voyagers decided to resort to pantomime.

Again Greenbough came out, bringing with him two small oxygen cylinders—one charged, the other empty—such as were part of the space-armor equipment. He first tapped on the charged cylinder, then briefly opened the valve so that a small quantity of the gas escaped with a sharp hiss. Then he repeated the performance with the empty cylinder—which of course produced no sound on opening the valve—and held it aloft toward the revolving swarm of watchers, pointing alternately toward it and toward the charged cylinder which he had laid at his feet.

A few of the bolder onlookers descended cautiously and extended hesitant tentacles toward the Earthling and his cylinders, their telegraphic light-organs flashing with agitated rapidity. He prepared to re-enact the dumb-show.

At the moment when Greenbough opened the charged cylinder the tip of an inquiring tentacle approached the valve. A lavender spark of static electricity snapped between valve and tentacle, and catastrophe ensued. The jet of oxygen in that atmosphere of methane and carbon disulphide vapor became a jet of brilliant blue flame emitting white fumes. Greenbough hastily closed the valve, but he had released a veritable cloud of death. Dozens of the baloon-bodied creatures collapsed, their anhydrous tissues corroded by water vapor, and fluttered downward like falling leaves.

The survivors fled in terror to their towers.

For some moments Greenbough was stunned by this disaster. Certain words of Akubii's darted through his brain.

"—if we can make ourselves understood . . . it may be that both of us shall return alive . . . otherwise . . . there will be scarcely enough air for one—"

"Akubii shall return," thought Greenbough, and raised a hand to open his face plate.

But the alert Martian in the *Peregrine* divined Greenbough's suicidal intent. The Earthling's will was paralyzed instantly by the impact of Akubii's mental prohibition.

"We are not yet entirely without hope, my impetuous one," Akubii's thought came to Greenbough, and he found himself re-entering the cruiser with the two cylinders.

THEREAFTER the *Peregrine* cruised widely over that frigid world, vaulted mountains rosy with ammonia snow, bored through thundering hurricanes that lashed her with whips of forked blue lightning, skimmed above vast forests of black squirming vegetation, approached a score of the turreted communities. And everywhere the rumor of the cruiser's coming went before it, so that the denizens of the towers remained behind their walls of salt or fled in panic.

At length the navigators abandoned the fruitless search and set the vessel upon a homeward space track, into the heart of the Galaxy. Ahead, the conning screen showed them infinite deeps powdered with a dust of suns, while the red star dwindled in their wake to a pin-point spark among innumerable sparks.

The total oxygen in the cruiser continued to diminish by small but remorselessly increasing decrements.

"There are two courses which we may pursue," announced Akubii. "Whenever we approach within reasonable distance of a star we may pause and see if it has a planetary system—and so lose time by stopping and starting. Or we may continue at maximum speed until—"

"Until all the oxygen has become helium," finished Greenbough. "And that will occur long before we enter charted space; you know that as well as I. That is, it will be so if there are two of us. If there were but one—"

"I refuse to discuss that alternative," Akubii declared, and stubbornly maintained this attitude.

Nevertheless, the Martian's implacable logic had thoroughly explored that alternative which he refused to discuss and had led him to a decision. During one of the rest periods which the navigators methodically observed, while Greenbough slept in his cabin Akubii was curiously occupied in his

own quarters. He seemed to be engaged in dismantling his bunk.

Under the bunk was a double bottom containing a shallow drawer. Akubii had unscrewed and removed portions of the bunk until he was enabled to take out the metal plate which formed the upper section of the double bottom. Then he proceeded to write upon what had been the under surface of the plate with a diamond-pointed glass cutting tool. He wrote deliberately but without hesitation, as one who had carefully premeditated his words. When he had finished he returned the plate to its former position with the writing underneath, reassembled the detached parts of the bunk, reclined on the nitrogen-inflated pad, and turned off the light.

For a time Akubii's cabin was in darkness, and there was silence in the *Peregrine* save for the faint smooth hum of her air-circulator. Then in the blackness of the Martian's cabin there appeared a foggily luminous object the size of a man's fist, blue-green like the glow of a feline eye, but indistinct as if shining through frosted glass, and veined with lines of shadow. It was an organ in the depths of Akubii's translucent brain and its luminosity denoted some supreme mental effort. It grew brighter and brighter, contracted spasmodically, and vanished.

We now quote directly from entries made by Greenbough in the photoscript log. It is to be understood that these were vocal recordings, and even after this great lapse of time they retain enough of their original quality to make it plain that the Earthling was in a state of emotional disturbance.

"Something has happened which I can't explain," says Greenbough. "It is a detached fact. It throws my logic into confusion. Ten hours ago I awoke to find that I had slept far beyond my usual interval. This isn't the fact to which I refer—it's what came afterward—but normally I am as regular as a clock in this respect. I was not refreshed by my slumber, but felt depressed and exhausted. Assuming that Akubii was in the control room, I went there, but did not find him. Neither was he in his cabin. In fact, a careful search has not found him anywhere in the ship.

"What has happened to Akubii seems clear enough. He cast himself from the air lock. His space armor has been removed from its locker and is nowhere aboard. He couldn't have left the ship without armor because the lock chamber must be evacuated of air before it will open outward. But here is the fact which baffles me. A faint trail of bootprints leads from *my* armor locker to the air lock and back—*my own prints*, made by the dust of Sulphuria packed between the ridges of the boot soles!

"They were not there before; I swabbed that bit of deck myself. They are unquestionably mine, and not Akubii's; they are the marks of boot soles formed to fit a human foot. Akubii couldn't wear my armor, nor I his. Even if Akubii did make the tracks he would have left a one-way trail, going out. And now that I think of it—*why didn't he?* He also was outside several times during our tour of Sulphuria, so there must been dust on his boots."

Greenbough later records himself as follows:

"In an effort to reconstruct whatever it was that happened I have scrutinized every corner of the ship from stem to stern, and have checked every item of our stores down to the last centimeter of silver wire. Nothing is missing save Akubii's armor, and only one thing is misplaced—a diamond glass cutter which I found in his cabin.

"I feel that the latter item is significant. It seems so meaningless that I am sure that it must mean something. If I knew what Akubii did in his cabin with the glass cutter perhaps, I should have the whole explanation."

We now quote Greenbough for the last time:

"Occasionally I wonder if this experience is unsettling my reason. I feel as if Akubii were still aboard. There is nothing queer or ghostly in the allusion; it has a quality of naturalness. Since he was voiceless, like all Martians, our interchange of thought was purely mental, and I am well acquainted with the sensation which always precedes transference—a fleeting impression that a sort of potential is building up in one's brain. This feeling recurs constantly, as if Akubii's mind were forever on the point of speaking to my own."

A cynical memorandum filed with the

photoscript log by the spaceport commander of *Aldebaran III* contemptuously dismisses Greenbough's explanation of the Martian's disappearance, refers caustically to its "feigned candor" and "assumed air of bewildered innocence." The commander was of the opinion that Greenbough either abandoned his companion on Sulphuria or murdered him aboard the *Peregrine* and threw body and armor from the air lock. He calls Greenbough's account "an elaborate but transparent fiction." The intuition of subsequent generations of spacemen who honored the legendary names of the two navigators are now revealed as more reliable than the deductions of a hard-headed skeptic.

HERE we conclude the narrative substantially as given in the *"Chronicles"* except for the incidents in the Martian's cabin just preceding his vanishment; that part is inferred from the archæological findings. Comparison with specimens of Akubii's Martian script from among his personal effects proves his authorship of the writing engraved on the metal plate. The translation of that writing is given verbatim herewith.

"This voyage has yielded certain fragmentary but extraordinarily significant information," Akubii wrote. "Our little bubble of a cruiser represents the concentrated thought, aspirations, and hope of millions of individuals. It must not fail to return and transmit this information into the common heritage of the Solar cultures. Within the confines of the regions permeated by those cultures—a microscopic point in cosmic immensity—we have found life to be rare and fragile phenomenon. Always it has been aqueous life, life built upon a foundation of water and oxygen. We believed that other kinds of life were possible but heretofore that belief has been entirely an act of faith. Now the first confirmation of that faith is in our hands.

"In our discovery of this world without oxygen, where perhaps sulphur takes the place of oxygen, we have laid the first stone of an edifice of wisdom which in time shall demonstrate beyond question that life is a local manifestation of a universal energy akin to the more familiar forms, an energy which is part of one whole with electromagnetism and matter and which insists on making itself manifest as if it were impelled by an indestructible will. This is not materialism but the very opposite. It is to say that those phenomena and things which we describe mistakenly as 'lifeless' should be designated by some other term; perhaps 'subvital' would be nearer the truth. It means that matter and energy in their various forms known and unknown may beget life. It means that the dust beneath our feet is merely slumbering, not dead. It means that earth and sky, and the space which we delude ourselves by calling 'empty,' are vibrant with incipient life and consciousness. It means that even if the entire Universe should be reduced by the flame of some all-encompassing disaster to the condition of the primal nebula, life would rise again in another time, on other worlds.

"With this justification for what I am about to do I now descend to certain minor considerations of immediately practical value. I have analyzed the behavior of our decarbonizer and have extrapolated the curve of its future performance. It is certain that our store of oxygen will not suffice for the return voyage if I remain, and may suffice if I do not. My consumption of oxygen is greater than Greenbough's; were I not here, the air would flow through the decarbonizer at less than half its present velocity.

"At first I considered abandoning ship in midspace, but it occurred to me that this would be wasteful since my body contains a not inconsiderable bulk of water and of oxygen otherwise combined.

"Therefore, while Greenbough lies deep in slumber I shall impose my will upon his and direct him to perform certain acts while in a state of hypnotic somnambulism. The memory of these acts shall be surrounded by what I hope will be an impenetrable barrier of forgetfulness, thereby sparing him a long voyage alone with the specter of a dreadful memory. And since my failure to return with Greenbough will make him liable to a grave, but unprovable, charge I shall also transmit to him a bit of information which will clear him in the ensuing investigation. This knowledge shall lie dormant until needed; then he will remember that I have told him of this record. But even when he reads my writing it will convey no more to him than to any other reader. Even then, I hope, he shall not remember more.

"Specifically, I shall instruct Greenbough to cast my space armour from the air lock so that afterward it will appear to him that such was the manner of my going. Then he shall do those things needful to reduce my physical self to its elements in our refuse incinerator. Having implanted these instructions in Greenbough's mind I shall compel myself by force of will to die.

"I am gambling on the posthumous power of hypnotic suggestion. If that fails, nevertheless, I shall be dead and the major purpose will be accomplished."

Thus ends the true and complete account of the last voyage of Greenbough and Akubii.

INTRODUCTION TO A NAMELESS SCIENCE

By Peter van Dresser

Probably the most unusual article Astounding has ever published, this material genuinely needs the editorial statement that its material is entirely factual. It opens out a completely new and unimagined field of research of deep interest to a dozen branches of existing science.

MAJOR TOMMY TOMLINSON, during a series of recent flights to test the feasibility of high-altitude all-weather flying, found several times that even at the 35,000-foot ceiling of his double-supercharged ship, he was thrown around badly by high winds, slashed by rain and hail, and in general presented with as fine an assortment of meteorological phenomena as one would expect to meet in front of a line squall at sea level.

The weather, it seems, is always with us—even seven miles up in the tropopause—recently dubbed the "substratosphere" by the press. However, seven miles is just a starter after all, and a few miles higher, when we are well into the stratosphere, things begin to calm down, if we can judge by sounding-balloon records and the experience of the few men who have ridden stratostats that high. In these altitudinous regions, a celestial—if somewhat frigid—serenity reigns perpetually. There are no winds because winds are primarily convection currents and the air is so rarefied that heat is transmitted from one layer to another by radiation before the currents have time to form. There is likewise no rain, hail, snow or similar discomforting manifestation, because there isn't any moisture to form rain, hail or snow. There are no clouds for the same reason. There isn't even any sky for clouds to float in, even in the daytime, because the molecules of the air are too sparse to do the necessary scattering of the sunlight below 5000 Angstroms, which produces sky-blue.

Twenty miles up—which is as high as the United States weather bureau data derived from sounding-balloon flights goes—the air pressure is down to about four-tenths of an inch of mercury—one seventy-fifth its value at sea level—temperature has dropped to around—44° F. and stays about constant, summer and winter; water vapor pressure is about one two-thousandth normal, and the sky is practically black. At this point we are obviously on the threshold of outer space. Sounding balloons—even the weather bureau's newest ones made on Sally Rand's molds!—can soar no higher; what little air floats above us soon becomes too rare even to register on the barometer and rapidly dwindles away into the void. Only a few vagrant signals reach us from regions higher than this—the occasional eerie

flicker of the northern lights and the evanescent darts of fire that are meteor trails. And beyond even these last outpost lights of the Earth there is nothing—nothing save the vast abyss of interplanetary space where, except for the few lonely planets which wheel around the central Sun, separated by inconceivable distances, all is unutterably cold and dead.

Or is it?

For generations this has been the conventional picture science has painted of our planet's lot in the cosmos. Now, however, we are not so sure of it. That "cold, dead, lifeless region" of outer space which lies beyond the Earth's atmospheric frontiers has begun to show some surprising signs of animation, at least to the microsensitive perceptions of twentieth-century science.

For about a century our physicists have been playing with electrical phenomena taking place in partial vacua. Beginning with such simple devices as the Geissler tube and the Crookes tube, they have discovered and harnessed one effect after another, until today civilization hinges on the operation of countless incandescent lamps, X-ray machines, thyratron converters, radio tubes, photo-electric cells, et cetera, et cetera—not to mention the neon lights that guide us to our beer oases. We have learned a great deal, and are daily learning more, of the amazing versatility of the reactions that can be produced in rarefied gases under varying conditions of heat, radiation, electrification, magnetism and the like.

Now suddenly—within the past few decades—it has dawned on us that while we have been tinkering with our bits of near-vacuum inclosed in glass, our diminutive filaments and cathodes and grids, nature is, and has been for geologic ages, conducting a few score miles above our heads the most gigantic experiments in vacuum-electronics imaginable, under conditions of magnitude, intensity and variety that we cannot dream of in our laboratories.

Empty space in these regions? "Eternally cold and lifeless void!" Nonsense. At twice the altitude where sounding balloons burst for lack of supporting air, our atmosphere is just warming up for action. In this vicinity its electrical conductivity is a thousand times what it is at sea level. And from here on upward, or outward, traces of the atmospheric sea reach for an indefinite distance—Sir James Jeans hazarded two thousand miles as his guess, which is conservative compared to other estimates. *And this vast hollow sphere of rarefied gases is in the ideal state for thermionic activity on a fabulous scale.*

In place of a filament heated by a few watts of current, this gigantic planetary vacuum tube uses as its source of radiant energy the Sun, which is continually pouring into it two hundred trillion horsepower of radiation from extreme ultraviolet to long infrared, not to speak of assorted electrons, ions, neutrons and possible other varieties of subatomic corpuscles which plunge into the atmosphere to various depths, according to their penetrating power, and keep the whole body of it in a more or less violent state of electrical agitation and ionization. In place of the minute anodes, cathodes, targets, grids, plates, et cetera, of our man-made vacuum tubes, this cosmic one employs entire planets and moons for its "elements." And in place of a sixty-ton magnet, our celestial supercyclotron uses one weighing six thousand million million million tons—that is, the Earth itself with its core of nickel-iron and its magnetic field extending out into space beyond the orbit of the Moon. And finally, in place of a few cubic centimeters or inches of glass-inclosed vacuum, these celestial electronic reactions take place within the whole vast volume of sublunar and even interplanetary space.

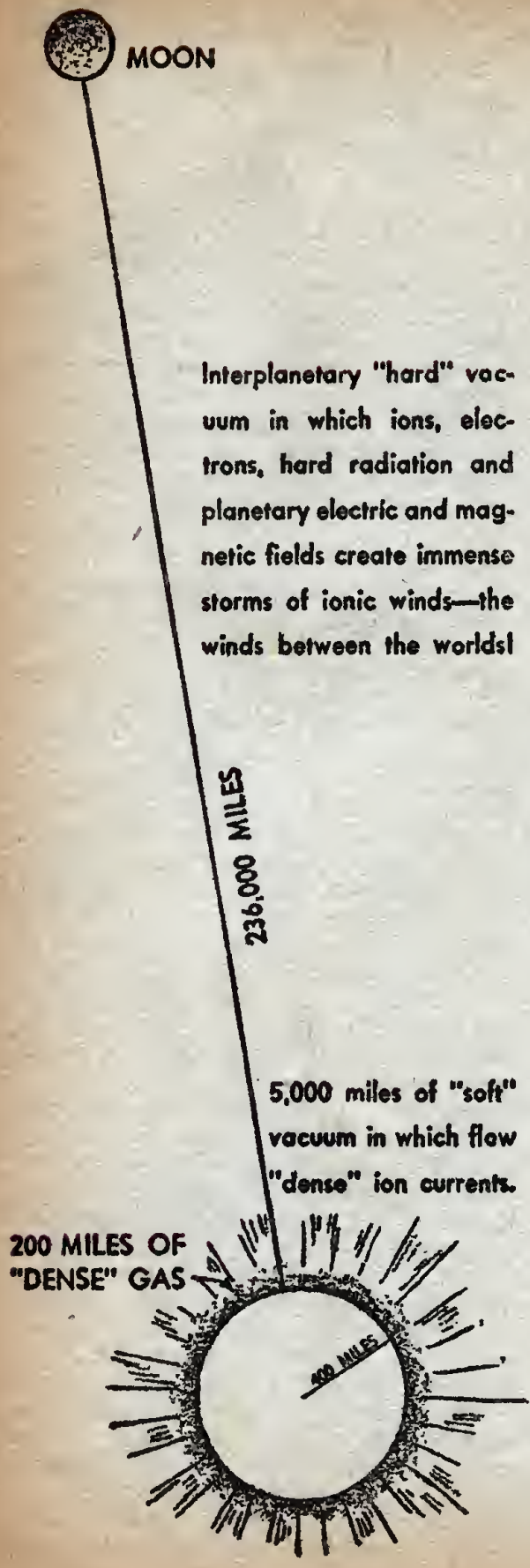
Looking at the matter in this light, we have begun to get some intimation of the sort of things that are happening above our heads in the extraterrestrial abyss, and of why mankind has remained so long ignorant of them. For the most part, these phenomena take place *without emission of visible light*—and until modern physics developed its present knowledge of, and means of detecting and measuring, the fifty-nine other octaves of electromagnetic radiation plus the various kinds of corpuscular emission, there was no reason for men supposing that what seemed to be empty space wasn't actually empty space.

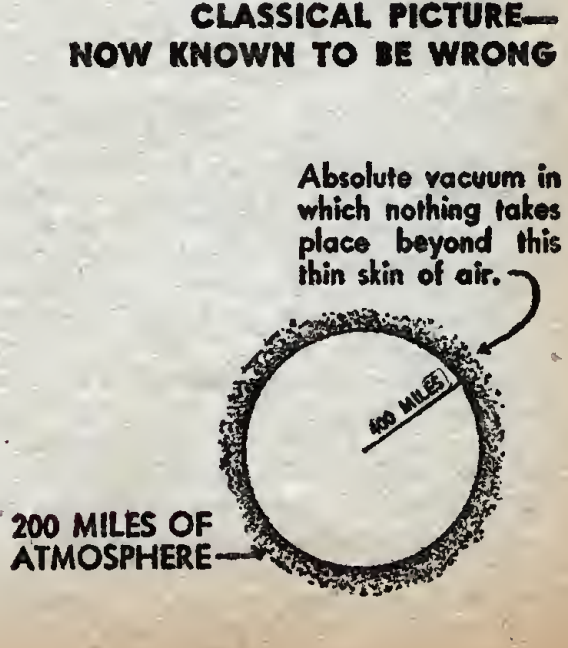
The first really vivid revelation of this new world for scientific exploration came at the turn of the century when Marconi and his co-workers discovered that, contrary to all reasonable expectation, Hertzian waves could be transmitted beyond the horizon—

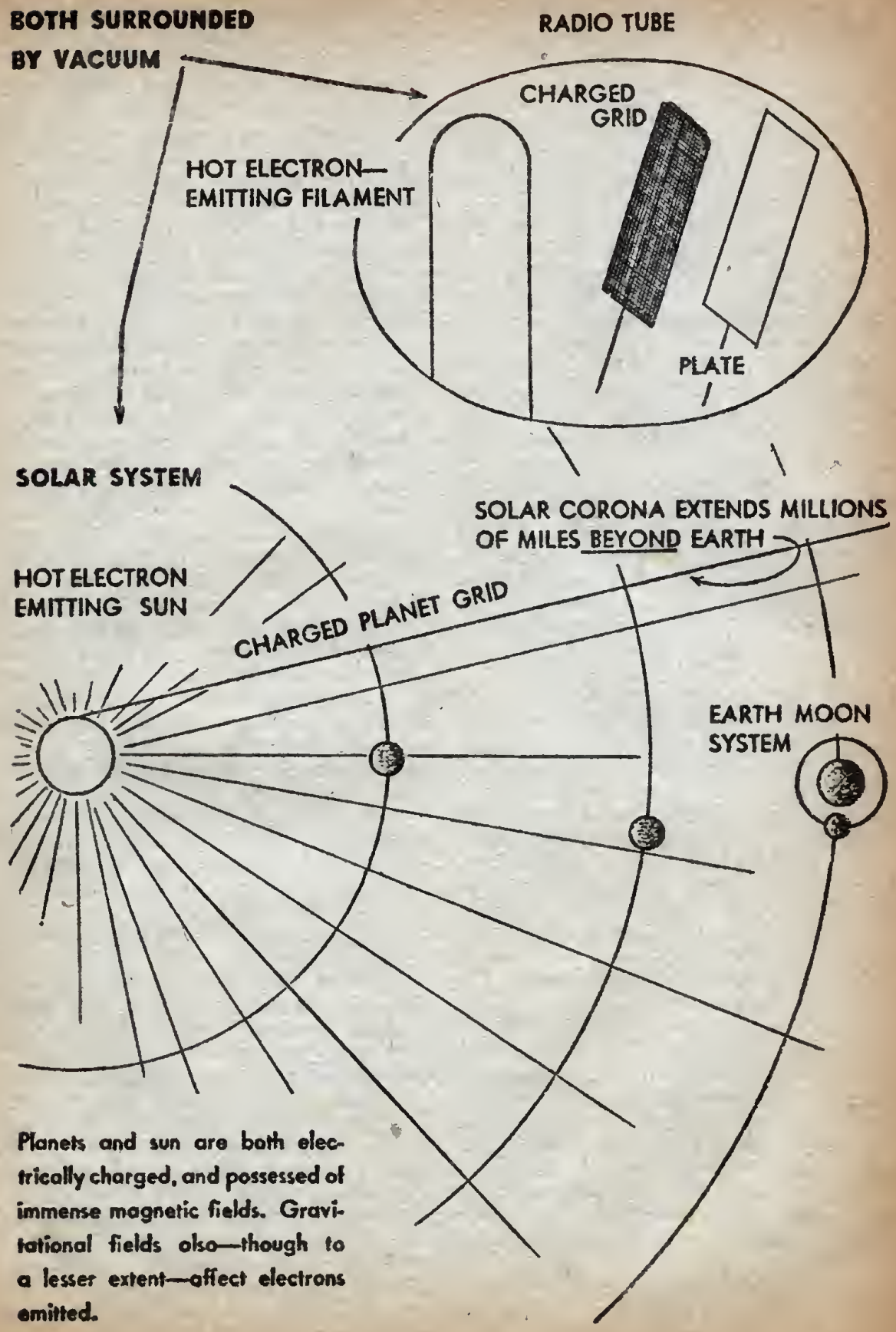
over the English Channel—even across the Atlantic! How this fact was eventually explained as due to the refractive action of a particular stratum of ionized gases—the Kennelly-Heaviside layer—hanging at high altitudes above the Earth is now old stuff in radio history. But the utter surprise of the first wireless experimenters is a measure of how completely unsuspected was the possibility of any measurable substance or phenomenon existing in the cosmic spaces surrounding our planet.

Even today science has hardly recovered from this shock and begun to organize an effective investigation of the new field. For one thing, it doesn't fit properly into any of the established subdivisions of scientific research. Whose business is it to break into the fresh territory?

It is true that radio engineers, as their technology developed, have made a point of gathering information concerning the behavior of the Heaviside layer—and the more recently detected and higher Appleton layer—in so far as this behavior controls communication at different frequencies, times and localities. But they have been primarily interested in interpreting this data from the empirical, practical point of view, so that it should be useful in planning the equipment of transmitting stations and in dispatching communications over suitable frequencies. They have not had the time or







Planets and sun are both electrically charged, and possessed of immense magnetic fields. Gravitational fields also—though to a lesser extent—affect electrons emitted.

incentive to interpret this information from the broad scientific viewpoint, to tie it in carefully with other known information bearing on the subject.

It is also true that the science of geophysics extends some of its observations into this field, particularly in the study of terrestrial magnetism—the intensity and direction of the Earth's magnetic field at various altitudes, and its fluctuations. But it is obviously illogical for a science concerned with purely terrestrial affairs to attempt to broaden itself to take in so many cosmic and astronomical factors.

Astronomers, for the reverse reason, do not feel too much at home in this cosmic-terrestrial no man's land. True, the mechanics of planetary and lunar motion, and the astrophysics of the Sun, are closely related with phenomena in this region—but what about all these other factors, radio reflections and Earth magnetism and atmospheric gases and so on? Astronomy is a deep-space science; its devotees prefer to be cruising out among the galaxies rather than picking their way through these uncertain onshore currents so close to home.

METEOROLOGY? The weather man, with his training in analyzing the movements of masses of air, his technique for measuring pressure, humidity, wind velocity, has no way of getting at, either physically or intellectually, this zone where measurable air pressure gives way to ion-density per cubic centimeter, where wind currents are replaced by electron streams and isobars by magnetic lines of force. Not that he isn't interested, however—for there are tantalizing hints of some sort of linkage between these ultra high-altitude goings-on and the air movements and weather cycles that are strictly his concern.

The pure physicist, of course, with his laboratory work on electromagnetics and electronics, has contributed the means by which this new frontier can be explored, but it isn't really in his province any more than astronomy—although he does occasionally leave his laboratory for field studies of cosmic ray distribution and penetration, or atmospheric electricity, or some other phenomenon with an astronomical or celestial tinge.

But obviously a really adequate exploration of this zone of cosmic terrestrial interactions implies the development of a new syncretic science, a blend of astronomy, astrophysics, geophysics, electronics, meteorology, climatology, and even, as we shall see later, biology. No such science exists officially yet, of course, but there are enough men breaking over into the new field from established bordering ones that pretty soon we will have to have a name for whatever it is they are studying. It might be called "astro-electronics," but it probably won't be. The University of Chicago, which under President Hutchins is a hotbed of slightly unorthodox educational trends, already has a department of its scientific school for the study of high-altitude electrical conditions which study it calls "ionology." A French meteorologist who is much interested in long-range weather prediction based on Solar analysis, has suggested "macro-meteorology," meaning something like the science of large-scale weather. The best known and probably most descriptive suggestion has been made, however, by the astronomer Harlan Stetson, former director of the Perkins Observatory, who has abandoned pure astronomy for the new hybrid and has created the department of Cosmic Terrestrial Research at Massachusetts Tech—probably the only department of this sort as yet existing. Dr. Stetson combines the accredited term *ecology*—the study of environmental influences—with *cosmos*, and thus evolves *cosmecology*, the study of our cosmic environment.

Putting together, then, information gathered from the fringes of a dozen established fields of research, we can already begin to form some idea of the territory our new syncretic science will cover and the kind of phenomena that are to be expected within this territory.

The first task is to reconstruct our traditional mental picture of the Solar System, inherited from classical optical astronomy. To the "cosmecological eye," the volume of space surrounding our Sun, and through which the inner planets circle, is no lifeless vacuum, but a sea of rarefied matter—cosmic dust, electrons, ions, and other kinds of corpuscles hurled out from the celestial inferno and speeding in all directions, impelled or guided by light pressure, by the tremendously intense magnetic fields occurring in sunspots, by the Sun's own magnetic field, by gravitation, by electrostatic space charges, or by other forces not understood. Evidence for this picturization

is varied and is mounting constantly. At the recently completed McMath-Hurlburt Observatory, spectrographic motion pictures of the Sun's surface have been made for the first time, and have shown that the agitation of the incandescent gases there is more violent and continuous even than had been suspected, that prominences are hurled outward to one or more times the diameter of the Sun and with velocities *equal to the velocity of escape*, so that even after they cool sufficiently to become invisible, the gases composing them continue their flight away from the Sun.

It is also known that the magnetic fields within sunspots reach intensities equivalent to a billion volts, which is easily powerful enough to hurl vast jets or fountains of corpuscles out into space. The most recent observations of the corona, the mysterious luminous halo surrounding the Sun, suggests that this zone of excited matter may even reach out and envelop the Earth—may actually be the cause of the zodiacal light which has not yet been satisfactorily explained. Certain peculiarities in the behavior of comets' tails have led astronomers to suggest that they are formed, not of matter streaming from the comet's head, but of material already floating in circumsolar space and ionized into luminescence by some sort of emanation from the head.

In addition to these manifestations of rarefied matter and speeding corpuscles, space, for immense distances out from the Sun, is flooded with an intense and ceaseless flood of radiation, notably the strongly ionizing ultraviolet which is now believed to be more intense than classical theory would indicate, due to the bombardment of the chromosphere by high-energy particles from the Sun's interior nuclear reactions.

Through this tenuous but violently energized sea of activated matter and radiation moves our own planet, inclosed in its own bubble of rarefied gases, its own gravitational and magnetic fields. Between this terrestrial space shell and the Sun's "sphere of influence," the reactions are continuous and complex. Charged particles from the Sun, streaming into the Earth's magnetic field, are gripped and drawn as by stupendous magnetic whirlpools toward the north and south poles. Here encountering the thin atmosphere fifty to several hundred miles high, they create zones and surfaces of ionization which, during periods of intense solar emission, glow with the weird beauty of the northern lights. And these ionizing streams or sheets of magnetically guided electrons are so well defined that at certain seasons they form reflecting surfaces thousands, even hundreds of thousands, of miles out in space; surfaces which will actually turn back short-wave radio signals as much as *thirty seconds* after they have been sent up from the Earth's surface.

Besides this electron bombardment, the oxygen and nitrogen—and possibly helium—of the upper atmosphere are kept more or less permanently ionized by ultraviolet radiation, and these two effects combined keep the Earth enveloped in a belt of ionized gases hundreds of miles thick and hanging a mere thirty-five to fifty miles above our heads.

Detecting, charting and analyzing the movements and changes of this *ionosphere* is an intricate and fascinating job, in some ways similar to the huge task of keeping track of world weather. For this ionosphere is no stable, quiescent thing. The forces which build it up are continually changing in relative intensity, and it is as continually responding to these changes. On the dark side of the Earth, for instance, the ion content of the upper air is always dropping off as the ultraviolet stimulus is removed, while on the sunlit side it is building up again—and this effect varies from latitude to latitude and from season to season.

The emissions and radiations from the Sun are also perpetually changing, with the eleven-year sunspot cycle, with the twenty-seven-day period of the Sun's rotation, with the accidental eruption of violent prominences in the chromosphere.

Other variable forces are ceaselessly at work in this cosmic laboratory. The Moon, as the Earth rotates beneath it, pulls definite barometric tide waves in the atmosphere, just as it does in the waters of the oceans. In some manner this lunar tide is accompanied by electrical and magnetic effects, for at certain magnetic observatories in the tropics the Earth's field strength changes as much as twenty per cent with the position of the Moon.

There is also evidence that the upper atmosphere is ionized by star-light, by cosmic rays, by the impact of the millions of meteors that strike it every twenty-four

hours. And to all these stimuli the Earth's sensitive outer skin responds rapidly. From day to day, hour to hour, season to season, it fluctuates in thickness and in height. Areas of high and low electron-density—corresponding to the weather man's cyclones and anti-cyclones—can be and are formed in the ionosphere, and can and do migrate from one region to another. In times of strong solar activity, these migrations take the form of powerful electronic currents. "Could we visualize the ethereal substance of the ionosphere as we visualize the surface of the ocean," writes Dr. Stetson, "we should find times when terrific storms were raging in this ionosphere. Here ions and electrons are being hurled hither and yon as though some great electrical wind played upon its surface, creating waves literally miles high." The movements of these electronic currents react according to the laws of electrodynamics and cause magnetic fields which interfere with the Earth's normal magnetism; they also, of course, raise hob with radio communications by shoving the Heaviside and Appleton layers around and sometimes even disrupting them entirely for short intervals.

Just what is the whole story of the interchanges of energy that take place at these high altitudes will not be known until much more research has been done. Tantalizing hints filter down to us. By studying the "skip distance" effects of the sound of heavy artillery fire, physicists have determined that at an altitude of about twenty-five to thirty-five miles there must be a zone of *very warm* gases—this in a region where by all previous notions the temperature should be approaching absolute zero. And somewhat higher still, meteor trails have been observed blown across the sky as if by invisible winds with velocities of hundreds of miles an hour. Can this be a stratum of intense convection currents set up by the heated gases below—a sort of "alto-troposphere" as it has been called by some meteorologists, or are these winds electrical in nature?

THEN there is that enigmatic radio "hiss" detected by Dr. Karl Jansky of the Bell Telephone Laboratories, emananting on the 14.6 wave-length apparently from the section of the Milky Way (rt. ascension 17^h30^m; decl. 10° South) toward which our Solar System is moving. Can this be caused by the collision of Earth's outer atmospheric frontiers with some sort of atomic particles drifting in space? There is also the curious green spectral line that Dr. Slipher of Lowell Observatory discovered present in the night sky at all times, and which he believes may be due to an unknown cosmic radiation. Intriguing, too, are the recent observations of that enigmatic cosmic particle, the mesotron or heavy electron, which, from its extremely short life history (about a millionth of a second) seems to be born in the upper layers of the atmosphere. How explain, also, the undeniable effect of the Moon on radio transmission which has been discovered by careful study of reception records in radio laboratories, and which is considerably greater than a purely barometric tide in the atmosphere would create? Has the Moon an electrostatic charge which acts on the ions of the upper air; or is there a possible gamma-radiation from the volcanic substance of the Moon's surface (such as has been observed in similar deposits on Earth); or is there a natural period of oscillation of the ionosphere which is a harmonic of the tidal period such that the tidal wave is reinforced periodically? Or are we dealing here with some more subtle effect still, such as a kind of grid action of the Moon on the stream of charged particles from the Sun? All these hypotheses have been seriously considered by scientists studying these phenomena in the great astroelectronic laboratory overhead.

Broader problems, more closely related to human life, are also involved in this study. Perhaps at last, in these new regions, we are on the track of that long-discussed linkage between sunspots and other cosmic phenomena, world weather, and even the ups and downs of the world's economy. So much empirical evidence on these matters has been gathered that scientists are glad of a mechanism by which such a linkage can be explained rationally and tested by observational and analytical means.

An enormous amount of work has been done, for example, by meteorologists in the attempt to show in what way variations in world weather are tied in with variations in the occurrence of sunspots. This has involved exhaustive planet-wide surveys of yearly storm tracks, of barometric pressure averages and rainfall distribution, for many

decades past. At first such surveys failed to bring up enough positive evidence to impress the general scientific world, but the more recent ones, based on broader knowledge, have begun to indicate that there are definite world-wide climatic cycles which keep step with the migrations of sunspots.

It is possible to go even further and show a very baffling correspondence between depressions and other mass manifestations, and the sun-spot cycle, for as far back as accurate observations go, which is several centuries. A decade or so ago science could only shake its head disapprovingly at such hypothesizing, but now—

If sunspots are powerful electro-magnetic projectors of atomic particles, and are also accompanied by flares of intense ultra-violet light—and if these emissions control the electrical tides and movements in the ionosphere—and if these tides and movements produce measurable effects of various sorts at the Earth's surface below—then the scientist can begin to admit the possibility that the mass fortunes and misfortunes of living beings here below *may* be in some way, and to some degree, influenced by these cosmic variables.

We already know that the sub-basement of the ionosphere, the ozone layer, does fluctuate in thickness with the amount of ionizing radiation it receives from the Sun, that these fluctuations control the amount of ultraviolet that filters to the Earth's surface, and that growing things, both animals and plants, are sensitive to and dependent on this radiation. It is by no means inconceivable that periodic variations in this portion of the sunlight that reaches the Earth's surface should be followed by periodic variations in the quality of man's food crops, their vitamin content, and so on—and this in turn by periodic variations in the mass vitality of the human race—which would be reflected in business activity and other mass manifestations.

ANOTHER such cosmic-terrestrial chain of cause and effect may be hinted at in the experiments of Professor Dessauer in Frankfort, who showed that our bodies react to the electrical character of the air we breathe. An excess of positive ions brought about higher blood pressure, fatigue and dizziness in his subjects, while an excess of negative ions banished these symptoms. We know that there are normally about five hundred ions per cubic centimeter in the air at sea-level, and that the proportion changes from night to day and with the seasons. Not enough observations have been made to determine thoroughly the laws of this change, but it is not unreasonable to suppose that the ions at the Earth's surface should respond in some manner to the space charge set up by the ion belt in the upper atmosphere. But this ion belt is controlled by the Sun and other celestial influences, and so—

There is even a place for the planets in this labyrinth of cosmic-terrestrial reactions and interactions. According to the dynamics of gravitational attraction, each planet must raise a tide in the solar atmosphere, the inner planets especially. The composite of all these tidal waves, acting in conjunction with the free vibration period of the solar atmosphere, may set up periodic damped oscillations strong enough to cause convection currents which whip the chromosphere into unusual activity, causing the eddies and whirlpools we know as sunspots—which in turn are accompanied by discharges of corpuscles and bursts of radiation—which in turn strike the Earth's atmosphere and set up electronic disturbances—which in turn—

But along about here we are getting so highly speculative and so uncomfortably close to astrology that even the boldest scientists begin to back water. Enough has been said, however, to show the variety and richness of the phenomena which fall within the scope of "cosmecology" and how much has yet to be learned about this "cold, lifeless vacuum" through which our planet is sailing.

The actual instruments and techniques by which cosmecological data are collected are about as varied as those of any single science could be.

Astronomical observatories, particularly those specializing in work on the Sun, Moon, meters and sky illuminations, supply a large part of the necessary information. Surveys and recordings of Earth magnetism and atmospheric electricity by geophysical institutes all over the world cover another important sector. Observations of the frequency, heights and spectrography of

auroral lights, such as are to be made by the Byrd expedition and have been carried on for years at a chain of remote stations in northern Scandinavia, are essential. Records of radio transmission for long periods between stations in various parts of the world (as, for example, the three-way exchange of astronomical time signals between Annapolis, Greenwich and Bordeaux) are an extremely important means of keeping track of ionic densities and migrations at high altitudes.

Direct soundings by means of echoes from radio signal transmitted vertically are another valuable means to this end, and are now made regularly at the Bureau of Standards, the Carnegie Institute, and several other stations around the globe. Records of sunlight intensity as kept by the three mountain stations established by Dr. Abbot of the Smithsonian Institution are of great importance. World-wide surveys of cosmic-ray penetration, as made by Millikan and Compton, throw light on the distribution of Earth magnetism at high altitudes and on the emissions reaching our atmosphere from outer space. The enormous amount of data gathered each year by the weather services of the various nations—particularly now that "raymetes," robot aërological balloons, are in wide use—furnishes a necessary substratum of information about upper air movements.

Incidentally, this new scientific importance of high-altitude data is the strongest current motivation for research on rockets. Dr. Goddard, who is working in close collaboration with the Smithsonian Institution, is primarily interested in developing his machines for solar and meteorological observations in the stratosphere, as are most of the other serious rocket-research men. The real need for accurate determination of the solar constant and of the solar spectrum, free of absorption effects due to the Earth's atmosphere, is far more likely to bring about the development of the high-altitude liquid-fuel rocket than is the possibility of mail carrying or trans-atlantic flights.

LIKE meteorology, the study of our "cosmic weather" must be largely a statistical science, co-ordinating and synthesizing observations of many sorts, taken at many different points on the Earth and over long periods of time. There are such various forces at work in the ionosphere, some irregular and some cyclic, that in order to sort them out, long-term averages and summations are necessary.

For example, in a recent survey made at Harvard University of the effect of the Moon's position on the transmission of signals from WBBM in Chicago, over fifteen hundred data cards were prepared. Each card represented a recorded value of the station's field intensity at the receiver set against the calculated value of the Moon's tide-producing force along the path of the signal, at the time in question—which value involved so much computing labor that it was necessary to use the Bureau of Standard's tide-predicting machine for the job. The fifteen hundred cards, representing two years of observations, were then compensated or "weighted" for *known* periodic effects on the signal transmission—for example, the twilight effect and the summer-winter variation. The weighted cards were then averaged in groups in such a way as to cancel out irregular variations due to local and accidental fading, static, et cetera. After thus eliminating, by statistical manipulation, the unwanted influences, final curves were worked up showing an unmistakable relation between the Lunar tide-producing force over the zone of the Earth's surface that was being studied and the efficiency of radio transmission through that zone—which in turn gave information about the corresponding variations in ion-density in the upper air.

Finally, the "cosmecologist" is prepared to look for data from all sorts of unexpected sources which throw light on the problem of co-ordinating terrestrial phenomena with celestial influences. Professor A. E. Douglass, an astronomer and director of the Steward Observatory at Tucson, discovered that the giant sequoias and redwoods of the Southwest have been acting for centuries as natural weather recorders, so that their rings give a perfect verification of the sun-spot-weather cycle for three thousand years past. For this neat trick, incidentally, he was given a $2,500 award by the Research Corporation. Other investigators have used wine vintages, records of the pelts of fur-bearing animals, and all sorts of vital statistics as a means of studying the integrated effect of cosmic environmental influences on life on Earth.

Biologists themselves, in fact, are becoming aware of this new ramification of their science. A great deal of research is being done on the effects of radiation on growth, the chromosomes, the functioning of the glands, et cetera, and there is now a regular International Congress of Electro-Radio-Biology. As knowledge in this field accumulates, much should be learned that can be related to the experiments that are constantly under way in the cosmic electro-radio laboratory overhead.

For centuries science has been disabusing us of the persistent primitive notion that the movements of the celestial sphere had something to do with *our* puny fortunes. Now, just when we have the lesson learned, it looks as if we'll have to start unlearning it. Apparently sunspots are not the only phenomena which move in cycles !

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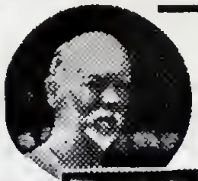

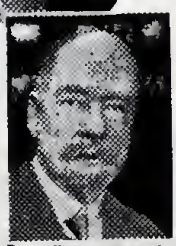

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PERMANENT *ELECTRET*

An electric charge is one of the most fluid things imaginable. The perfect insulator does not exist. The binding that will tie down a few million electrons in one place, leaving a few million atoms short electrons somewhere else seemingly doesn't exist. They always leak back.

Though the electric and magnetic fields are much alike in many ways, then, scientists have had permanent magn-ets, but no permanent electr-ets. Rubbing a bar of hard rubber with a bit of fur gives a temporary electret, good for a five-minute experiment. It was possible to work with it if you first measured its rate of leakage and took that into account. It was a nuisance of the first water. But—such things as permanent electrets, a condenser that wouldn't discharge, didn't exist.

They've made 'em finally. A permanent magnet consists of iron, cobalt or nickel crystal-units, each a natural, tiny magnet, all lined up in orderly arrangement by the application of an external field and held there. If the metal is magnetized while red-hot, and allowed to cool in a magnetic field, the magnetization is more powerful because the cooling freezes the magnet-units in position.

There are certain electrically unbalanced molecules—ordinary soap molecules, for one, but there are many others, too—which an electric field can line up. It's been found that these can be lined up under proper conditions, and, if cooled in a powerful electric field, frozen in the ordered arrangement. Presto! The long-sought permanent electret! It acts like a fur-rubbed bit of hard rubber—except that no amount of short-circuiting will wipe the charge off. Made into a condenser, it represents the curious anomaly of an electromotive force that won't motivate! There's voltage there, all right, and you can detect it and measure it with the proper means, but it won't produce a current.

As yet, the method and the electrets are too new to have been applied in any practical, widespread way. Suggested uses, however, are popping up rapidly. For one thing, they may make possible an electrostatic voltmeter of reasonable low-voltage sensitivity, replacing with permanent electrets and electric fields the present permanent magnets and magnetic fields. And electrostatic voltmeters have the pleasant property of measuring voltage without drawing on it.